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This Multimedia Technical Support Document presents the technical data base developed by the Industrial Technology Division of EPA for the ethanol-for-fuel point source category. Data were originally collected between 1979 and 1981 with the intent of using them as the basis for proposing effluent limitations guidelines. However, in early 1982, an EPA policy decision was made to develop guidance for the Ethanol-for-Fuel industry instead of effluent limits. This decision was made because of the decline in the growth of this industry when foreign crude oil became more available and the fuel shortage was somewhat abated. This document discusses various source of pollution generated from the ethanol-for-fuel facilities on a multimedia basis: for air, water, and solid waste. Also, various pollutants of concern associated with media waste stream are listed. These lists come from an extensive data gathering program also discussed in this document. A presentation of pollution control alternatives for each media waste stream is also included followed by discussion of costs for some of these control systems.

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for the
ETHANOL-FOR-FUEL INDUSTRY

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DISCLAIMER

This Multimedia Technical Support Document was primarily based on the EPA/EGD Multimedia sampling and analysis program. Data were also obtained from NPDES permits, an EPA Region IV Surveillence and Analysis Division Program, the IERL-Ci Source Test Evaluation, published literature and EPA supported engineering calculations. No proprietary or confidential data appear or have been used in the preparation of this document. Although this document addresses various wastewater treatment technologies, no process developer or process licensee was involved in the development of this manual. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

FOREWORD

This Multimedia Technical Support Document (MTSD) provides process, discharge and pollution control data in summarized form for the use of permit writers, developers, and other interested parties. This document presents examples of control technologies both as individual process units and as integrated control trains. These examples may be taken in part from applicable NPDES or other permit applications and, therefore, reflect specific plants. None of the examples are intended to convey an Agency endorsement or recommendation but rather are presented for illustrative purposes. The selection of control technologies for application to specific plants is the exclusive function of the designers and permitters who have the flexibility to utilize the lowest cost and/or most effective approaches. It is hoped that the readers will be able to relate their waste streams and controls to those presented in this document to enable them to better understand the extent to which various technologies may control specific waste streams and utilize the information in making control technology selections for their specific needs.

The reader should be aware that this document contains no legally binding requirements or guidance, and that nothing contained in this document relieves a facility from compliance with existing or future environmental regulations or permit requirements.

ABSTRACT

This Multimedia Technical Support Document presents the technical data base developed by the Effluent Guidelines Division of EPA for the ethanol-for-fuel point source category. Data were originally collected between 1979 and 1981 with the intent of using them as the basis for proposing effluent limitations guidelines. However, in early 1982, an EPA policy decision was made to develop guidance for the Ethanol-for-Fuel industry instead of effluent limits. This decision was made because of the decline in the growth of this industry when foreign crude oil became more available and the fuel shortage was somewhat abated.

The ethanol-for-fuel industry is defined as those commercial-size (greater than one million gallons of ethanol per year) facilities that convert biomass (via fermentation) to ethanol for use as a fuel. On September 1, 1981 the ethanol-for-fuel industry consisted of 15 such facilities with a total annual capacity of 164 million gallons. Thirty-five plants with a total capacity of 705 million gallons per year were under construction, and 42 plants with a total capacity of 980 million gallons per year were proposed. Approximately one-fourth of the existing plants (in operation and under construction) were direct dischargers (or discharging directly into a surface water body).

In September 1985, there were 102 plants in 31 states, each with a capacity of 1 million gallons per year or more. Out of these 102, there were 57 plants in operation and producing, with capacity of approximately 764 million gallons per year. In 1985 there were 15 plants under construction in 12 states, with a capacity of 220 million gallons per year.

This document discusses various sources of pollution generated from the ethanol-for-fuel facilities on a multimedia basis: for air, water, and solid waste. Also, various pollutants of concern associated with each media waste stream are listed. These lists come from an extensive data gathering program also discussed in this document. A presentation of pollution control alternatives for each media waste stream is also included followed by a discussion of costs for some of these control systems.

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In regard to biomass sources, the pollution control strategies discussed in this document for the ethanol-for-fuel industry pertain to facilities that use grain, wood sugar, cane and citrus molasses, and cheese whey as feedstocks. Biomass sources such as cellulose, sugar crops (i.e., sweet sorghum, sugar beets, and sugar cane), and potatoes could not be addressed with the information available at the time this document was completed.

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SECTION 1

INTRODUCTION

The purpose of this document is to provide guidance to permit writers, industry, and the general public on multimedia pollution control systems for the ethanol-for-fuel industry. Information is provided on ethanol-for-fuel waste stream characterization, process descriptions, and pollution control options and costs on a variety of ethanol-for-fuel facilities.

The term "Ethanol-for-Fuel" in this document concerns only the ethanol derived from biomass through fermentation. Ethanol can also be derived from ethylene and ethanol derived in this fashion is called synthetic ethanol. However, synthetic ethanol is not considered as a source of ethanol for the Ethanol-for-Fuel industry evaluations. Fermentation ethanol was first used as a fuel in the United States in the late 1800's; in the early 1900's ethanol was used both in stationary and mobile combustion applications. By the end of World War II, ethanol production in the United States totaled 600 million gallons per year. Using ethanol as a fuel decreased after the war and nearly disappeared until the late 1970's when interest was renewed because of concern over dependence on insecure foreign oil supplies.

In light of this potential new industry, in 1979 the Agency initiated the gathering of data with the intent of proposing multimedia environmental regulations on the ethanol-for-fuel industry. In January 1981, the Federal government cut back on financial assistance for ethanol production. This action, along with high corn prices and a more stable supply of petroleum resources, resulted in a steep cutback of ethanol-for-fuel production. In early 1982, the Agency reached the decision to utilize the data gathered to provide guidance rather than issue formal regulations on pollutant discharges in the ethanol-for-fuel industry.

The Multimedia Technical Support Document (MTSD) contains no legally binding requirements, no regulatory standards and includes no preference for process technologies or controls. Nothing within this document binds a facility to accepting the example control technology(ies) nor relieves a facility from compliance with existing or future environmental regulations or permits.

1.1 TECHNOLOGY OVERVIEW

All fermentation alcohol plants employ four basic processes: feedstock preparation, fermentation, distillation and dehydration. A fifth process, byproduct recovery, is also possible, but not necessarily included in all ethanol-for-fuel plants. Variations within the fermentation, distillation and dehydration processes do not result in significant changes in the quality or amount of emissions or effluents from a facility. Both feedstock preparation and byproduct recovery process variations have greater impact on the characteristics of the generated wastes.

Feedstock Preparation

Feedstock preparation includes all steps in converting the raw material to a saccharified mash. Depending on the feedstock, different methods of preparing the saccharified mash and for removing valuable byproducts, such as germ or lignin, are available. The feedstock preparation techniques in use in the existing ethanol-for-fuel industry include: dry milling, wet milling, wood sugar preparation, and cheese whey preparation.

Fermentation

The biological conversion of the saccharified mash by yeast for the production of ethanol can be rendered in continuous or batch fermentation processes. The grain and wood sugars are converted into ethanol and carbon dioxide. Other reactions also occur producing small quantities of acetic acid, aldehydes and longer chain alcohols.

Continuous and batch fermentation processes require temperature control, agitation and pH control. Fermentation is an exothermic process and cooling is usually employed for temperature control. Depending on the choice of fermentation process, the fermented mash will vary with respect to yeast reclamation, vessel residence time, live yeast concentration and ethanol concentration. These four parameters are closely interrelated and require special attention for the maintenance of steady state operation.

Distillation

In the distillation process the ethanol is removed from the solids and most of the water. The process variations in the distillation chain are a function of desired product quality. Those plants which produce potable as well as fuel-grade ethanol include additional stills to remove nearly all organic contaminants (e.g., fusel oils and aldehydes) whereas new grass roots ethanol-for-fuel plants are designed to minimize energy requirements and wastewater generation.

Dehydration

When a mixture of ethanol and water is distilled, a minimum boiling point azeotrope is found. At this point (96 percent ethanol) further separation of ethanol and water is impossible using simple distillation. To produce anhydrous ethanol, a third compound, the dehydration agent, can be added to the mixture to alter the azeotrope and subsequently permit the removal of all water from the ethanol. This is the most common technique used in the dehydration of ethanol to be used as fuel.

Byproduct Processing

The method of byproduct recovery is dependent upon the feedstock and the feedstock preparation technique employed. The stillage from the bottom of the beer still is often recovered as a marketable, high-protein byproduct but may be discharged as wastewater. In some cases, the quantity and/or quality of stillage does not warrant the capital expenditure required for byproduct recovery, particularly if feedstocks other than grain are used. Those plants which do recover the stillage utilize dewatering and drying processes such as cyclones, evaporators and dryers for complete recovery of a dry solid. Those plants that do not recover stillage have a substantially higher wasteload since the byproduct recovery system is the major contributor to total distillary wastes.

1.2 REGULATORY BACKGROUND

Wastewater Regulations

The Federal Water Pollution Control Act of 1972 established a comprehensive program to "restore and maintain the chemical, physical, and biological integrity of the Nation's waters" [Section 101(a)]. By 1 July 1977, existing point source industrial dischargers were required to achieve "effluent limitations requiring the application of the best practicable control technology currently available" (BPT) [Section 301(b)(A)]. Further, by 1 July 1983, these dischargers were required to achieve "effluent limitations requiring the application of the best available technology economically achievable (BAT) which will result in reasonable further progress toward the national goal of eliminating the discharge of all pollutants" [Section 301(b)(2) (A)]. New industrial direct dischargers were required to comply with Section 306 new source performance standards (NSPS), based on best available demonstrated technology (BAD), and new and existing dischargers to publicly owned treatment works (POTWs) were subject to pre-treatment standards under Sections 307(b) and (c) of the Act. While the requirements for direct dischargers were to be incorporated into National Pollution Discharge Elimination System (NPDES) permits issued under Section 402 of the Act, pretreatment standards were made enforceable directly against dischargers to POTWs (indirect dischargers).

Although Section 402(a)(1) of the 1972 Act authorized the setting of requirements on a case-by-case basis, Congress intended that, for the most part, control re- quirements would be based on regulations promulgated by the Administrator of the EPA. Section 304(b) of the Act required the Administrator to promulgate regulations providing guidelines for effluent limitations setting forth the degree of effluent reduction attainable through the application of BPT and BAT. Moreover, Sections 304(c) and 306 of the Act required promul- gation of regulations for NSPS, and Sections 304(f), 307(b), and 307(c) required promulgation of regulations for pretreatment standards. In addition to these regulations for designated industry categories, Section 307(a) of the Act required the Administrator to promulgate effluent standards applicable to all dischargers of toxic pollutants. Finally, Section 501(a) of the Act authorized the Administrator to prescribe any additional regulations "necessary to carry out his functions" under the Act.

On 27 December 1977, the President signed into law the Clean Water Act of 1977 (P.L. 95-217). Although this law makes several important changes in the federal water pollution control program, its most significant feature is its incorporation into the Act of several of the basic elements of the Settlement Agreement program for toxic pollution control. Sections 301(b)(2)(A) and 301(b)(2)(C) of the Act now require the achievement, by 1 July 1984, of effluent limitations requiring application of BAT for toxic pollutants, including the 65 toxic pollutants and classes of pollutants which Congress declared toxic under Section 307(a) of the Act. Likewise, the EPA's programs for new source performance standards and pretreatment standards are now aimed principally at toxic pollutant controls. Section 306(b) includes a list of industrial categories for which these performance standards should be developed. Moreover, to strengthen the toxics control program, Congress added Section 304(e) to the Act, authorizing the Administrator to prescribe "best management practices" (BMPs) to prevent the release of toxic and hazardous pollutants from plant site runoff, spillage or leaks, sludge or waste disposal, and drainage from raw material storage associated with, or ancillary to, the manufacturing or treatment process.

In keeping with its emphasis on toxic pollutants, the Clean Water Act of 1977 also revised the control program for nontoxic pollutants. Instead of BAT for "conventional" pollutants identified under Section 304(a)(4) (including biochemical oxygen demand, total suspended solids, fecal coliform, pH, and oil and grease), the new Section 301(b)(2)(3) requires achievement, by 1 July 1984, of "effluent limitations requiring the application of the best conventional pollutant control technology" (BCT). The factors considered in assessing BCT for an industry include the costs of attaining a reduction in effluents and the effluent reduction benefits derived compared to the costs and effluent reduction benefits from the discharge of publicly owned treatment works [Section 304(b)(4)(B)]. For nontoxic, nonconventional pollutants, Sections 301(b)(2)(A) and (b)(2)(F) require achievement of BAT effluent limitations within three years after their establishment or 1 July 1984, whichever is later, but not later than 1 July 1987. Table 1-1 summarizes these levels of technologies, sources affected, and deadlines for promulgation and compliance.

BPT, BCT, BAT, and NSPS have not been developed for the ethanol-for-fuel industry. This industrial category was not listed among those in Section 306(b) of the Clean Water Act. Yet in 1979, when it appeared that the industry was growing at a rate requiring regulatory control, the Agency initiated a regulation development program. However, by 1981 when projected growth of the industry substantially declined, the Agency made the decision to develop guidance rather than regulations. The difference between the two is that regulations are legally binding standards that require compliance. "Guidance" on the other hand simply provides information which permit writers and industrial developers can use (among other sources) in their determination of appropriate pollution control measures.

Air Regulations

The Clean Air Act and its amendments created a comprehensive program to protect and enhance the Nation's air quality and a regulatory scheme for the control of air pollution. The cornerstone of the Act is the development of uniform national ambient air quality standards (NAAQS). The responsibility for limiting emissions to meet the ambient standards lies with the states. The Act required each State to develop state implementation plans (SIPs) which provide for implementing, maintaining, and enforcing the ambient standards.

The Act also requires the United States Environmental Protection Agency to establish three sets of nationally uniform emission limitations: new source performance standards (NSPS), hazardous pollution emission standards, and motor vehicle emission standards. The NSPS requires the application of "best demonstrated technology" to new and modified stationary sources. However, the Act allows the States to require more stringent emission limitations than those developed for NSPS.

Part C of the Act, prevention of significant deterioration of air quality, provides EPA a means to regulate any pollutant from any major emitting facility which may adversely affect the public health and welfare. A major emitting facility for the ethanol-for-fuel industry would be any source which emits or has

Table 1-1

THE CLEAN WATER ACT AMENDMENTS OF 1977

Level of Technology	Section of Act	Sources Affected	Deadline for EPA for Promulgation	Deadline for Operator Compliance
BPT	301, 304	Existing sources	1 yr. after passage	1 July 1977
BAT	301, 304	Existing sources	1 yr. after passage	1 July 1984
BCT	301,304	Existing source	1 yr. after passage	1 July, 1984
BADT	306	New sources	1-1/3 yrs. after passage	Effective upon promulgation
PSES	307	Existing sources discharging to POTW	270 days after passage	No later than 3 years after promulgation
PSNS	307	New sources discharging to POTW	1-1/3 yrs. after passage	Effective upon promulgation

the potential to emit 227 metric tons/year (250 tons/year) or more of any pollutant.

Solid Waste Regulations

The issue of federal legislative control for the safe disposal of solid waste has been a primary environmental concern in the 1970's. Initially, regulation of solid waste was solely the responsibility of the states. Later, federal solid waste programs were promulgated such as the Solid Waste Disposal Act of 1965 and the Resource Recovery Act of 1970. However, neither of these acts gave any enforcement authority for solid waste control to the federal government. In order to obtain more uniform solid waste control the Resource Conservation and Recovery Act (RCRA) was passed in 1976.

RCRA was designed with the following principal features: regulation of certain wastes, defined or characterized as hazardous, are to be the responsibility of the federal government; and regulation of nonhazardous wastes is to be a state responsibility, in conformance with federal guidelines. However, under RCRA Section 3006, states are authorized and encouraged by EPA to develop and carry out their own hazardous waste programs in lieu of a federally administered program. Authorization for state run programs must be granted by EPA and is being initially administered through an "interim status" program. "Final authorization" will be possible after Section 3004, Part 264 requirements are promulgated.

For solid wastes, the prevailing factor is whether the waste is considered hazardous or nonhazardous under the Resource Conservation and Recovery Act. If one or more of the solid waste streams generated by ethanol-for-fuel facilities are considered hazardous, the Administrator has the authority to "list" such streams. When this occurs the generators, transporters, and disposers of these wastes must comply with all appropriate Subtitle C regulations of the Resource Conservation and Recovery Act (RCRA 3000 Series). Wastes which are not hazardous are subject to Subtitle D regulations (RCRA 4000 Series).

Additionally, there are regulations which deal with the reuse of hazardous wastes. Under Section 3001, part 261.6, a hazardous waste which meets specific criteria is excluded at this time from some of the waste management requirements if it is always used, reused, recycled, or reclaimed.

Prior EPA Regulations

The ethanol-for-fuel industry consists of facilities that convert biomass to ethanol for use as a fuel. It is a new industry which, for the most part, consists of converted beverage alcohol plants. A review of environmental regulations reveals that there are no federal regulations which apply specifically to the effluents, emissions, or solid wastes generated by either ethanol-for-fuel facilities or beverage alcohol facilities. In the absence of effluent guidelines, National Pollutant Discharge Elimination System (NPDES) permits have been issued to distillers based on a permit authority's "best professional judgment" under authority of Section 402(a)(1) of the Federal Water Pollution Control Act. Also, state pollution control boards have been responsible for monitoring and regulating air emissions and solid wastes for existing ethanol facilities based on "best professional judgment."

1.3 INDUSTRY OVERVIEW

As of September 1981, there were 15 plants which comprised the ethanol-for-fuel industry. The combined capacity of these plants was 600 million liters (163.5 million gallons) of ethanol per year. At that time there were six beverage alcohol plants being converted to produce ethanol-for-fuel and 29 new facilities under construction. The plants under construction were estimated to have a capacity of about 2.5 billion liters per year (705 million gallons per year); most of these plants were scheduled to be on-line by 1985. In addition, there were 42 plants under study or planned. The combined capacity of these proposed plants was approximately 4.3 billion liters per year (1 billion gallons per year).

In January 1984, a total of 70 ethanol-for-fuel plants were in existence. Of these 70, however, only 43 were operational. The capacity of these 70 plants was approximately 2.6 billion liters per year (683 million gallons per year). (1) An industry profile later performed in September 1985 showed a total of 102 ethanol-for-fuel plants in existence.* Of these, 57 were in operation and producing. The total capacity of the 102 plants was 3.6 billion liters per year (941 million gallons per year). The 57 operating plants had a capacity of 2.9 billion liters per year (764 million gallons per year). At this time, there were also 15 plants under construction in 12 states with a capacity of approximately 220 million gallons per year. There were 38 proposed plants (capacity of 593 million gallons per year) with another 36 projects "on hold."

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*Note: All the data collection, literature searches, analyses, statistics, and costing for this document were completed in 1981. Prior to publication in 1986, however, an updated industry profile (September 1985) was included in this document for informational purposes. EPA believes, however, that the industry has not changed significantly enough in the past four years to warrant an entire reanalysis of the 1981 data.

Grain is the major feedstock for these facilities. Approximately 94 percent of the alcohol from the plants under construction will be derived from grain. The remaining ethanol will be produced from wood sugars, corn syrup, and other biomass sources.

In the late 1800s, fermentation ethanol was used for cooking, heating, and lighting. During World War II, ethanol was used for fuel in submarines, aircraft, and land vehicles, as well as in the production of synthetic rubber. However, after the war, gasoline became plentiful and inexpensive, and industrial ethanol was produced by a more economical method using ethylene. The interest in fermentation ethanol was renewed by the Nebraska legislature in 1971 when the state tax on gasoline was reduced for fuels containing grain-derived ethanol. Public interest continued, and the Department of Energy, United States Department of Agriculture, White House, and Congress were encouraging research and development of ethanol for fuels.

1.4 DATA COLLECTION METHODOLOGY

To compile a data base for the evaluation of pollution control in the ethanol-for-fuel industry, information was gathered from the literature; beverage and ethanol-for-fuel facilities; trade organizations such as the Distilled Spirits Council of the United States (DISCUS), the National Gasohol Commission, the National Alcohol Fuels Commission, and the National Alcohol Fuels Producers Association; and government agencies such as the DOE, EPA, and Bureau of Alcohol, Tobacco, and Firearms (ATF). Data obtained from these sources included information on ethanol production; location and distribution of ethanol-producing facilities; process descriptions; water use; sources of wastewater, air emissions, and solid wastes; pollutant concentrations; and cost and treatability of control and treatment technologies.

The data base collection efforts included contacts with government and industry personnel, a program for sampling eight ethanol distilleries, and preparation and submittal of two industry questionnaires to 15 distilleries under authority of Section 308 of the Clean Water Act, Sections 111 and 114 of the Clean Air Act, and Section 3007 of RCRA. Also conducted as part of the data gathering effort was a review of the NPDES monitoring data on file with regional EPA offices, and a review of the information contained in the 1974 draft development document for the Beverages Segment of the Miscellaneous Food and Beverage Industry concerning the beverage alcohol industry.

After the data base was analyzed, the major sources of wastewater, air emissions, and solid wastes were identified and their contribution to total plant waste load quantified. The total plant wastewater characteristics were summarized in terms of pollutant concentration for the toxic (129 priority pollutants), conventional, and nonconventional pollutants. Also, point source and fugitive air emissions were estimated for criteria pollutants (NO_x, SO_x, and particulates) and volatile organic compounds on a plant-by-plant and industry-wide base. Finally, all solid wastes, plant feedstocks, and by-products were evaluated for the characteristics of ignitability, corrosivity, reactivity, and EP-toxicity.

The determination of wastewater pollutants of concern was based on toxicity of pollutants, wastewater characteristics and the treatability of these species by control and treatment technologies.

The control and treatment technologies applicable to the industry were assessed. Included were in-plant and end-of-pipe technologies which are used in the industry or can be adapted to it. The identified technologies were evaluated for their ability to treat the pollutants of concern. The problems, limitations, and reliability of each control and treatment technology were also identified.

In addition to treatability, the cost of treatment has been considered in developing pollution control systems. Thus, this document includes an evaluation of the cost associated with purchase, installation, and operation of wastewater treatment equipment. Capital costs, annual costs, energy requirements, and land requirements were developed for new plants and for retrofitting existing plants. Cost information was obtained from the industry during plant visits, from engineering firms, from equipment suppliers, and from the literature. Where data were lacking, costs were developed from knowledge of necessary equipment, processes employed, and construction and maintenance requirements.

1.5 DOCUMENT ORGANIZATION

This Multimedia Technical Support Document is presented in seven sections and seven appendices. Following this introductory section are:

> Section 2 - Industry Profile - The industry profile contains information on the history of ethanol production, process descriptions, total plant capacities, and other important statistics, as well as water use and management practices within the ethanol-for-fuel industry. This profile provides a foundation for analysis of water use and wastewater generation and treatment.
>
> Section 3 - Waste Stream Characterization - The data collected on the levels of pollutants in air emissions, wastewaters and solid wastes from ethanol facilities is summarized and evaluated in Section 3. Included are the test

results from two EPA sampling programs and monitoring data obtained from several distilleries. Also included is a discussion of the major sources of emissions and effluents and their composition and treatability.

Section 4 - Wastewater Treatment and Control Technology - This section discusses applicable in-plant and end-of-pipe technologies which can be used to reduce or eliminate the pollutants of concern. The achievable effluent pollutant reductions are discussed using treatability information from the beverage alcohol and ethanol-for-fuel industries. The applicable technologies are further analyzed according to their cost effectiveness, energy requirements and secondary pollutant potential.
Section 5 - Solid Waste Treatment and Disposal Technologies - This section discusses applicable solid waste treatment and disposal techniques including dewatering, drying, digestion, land application and recycle/reuse. These techniques are analyzed based on effectiveness, availability, current use and cost.

Section 6 - Cost, Energy and Nonwater Quality Issues - Cost, energy and nonwater quality issues are discussed for each treatment technology. Cost and energy information contained in this manual was obtained from industry during plant visits, from engineering firms, from equipment vendors, and from the literature.

References.

Appendix A - Sampling procedures used to collect field wastewater, solid waste and gaseous emissions.

Appendix B - Analytical methods and preliminary sample treatment on preparations used to analyze the collected samples.

Appendix C - Quality assurance/quality control procedures to assure, assess and document the precision, accuracy, and adequacy of the data.

Appendix D - Solid waste and air sampling results - compilation of analytical data.

Appendix E - Wastewater sampling results - raw and treated effluent analytical data.

Appendix F - Statistical support calculations.

Appendix G - Appendix G is the Ethanol-for-Fuel Effluent Guidelines Cost Manual which presents a detailed evaluation of the costs and energy requirements associated with treatment and control alternatives discussed in this manual.

SECTION 2

INDUSTRY PROFILE

This profile of the ethanol-for-fuel industry consists of a short historical background on the ethanol industry; status of the industry, including information on production capacity, location, number of plants, feedstocks, by-products, and plant age or on-line dates for proposed plants; and a discussion of ethanol-for-fuel processes.

2.1 HISTORICAL DEVELOPMENT

The production of ethanol originated with the discovery that alcoholic beverages could easily be obtained by fermenting substances with naturally occurring sugars such as fruit. The production of ethanol from grain is a more complex process because the starch must be converted to sugar before fermentation; however, even this technique was known in ancient times. The Egyptians and Mesopotamians brewed beer as early as 2500 B.C., and these processes were used until the middle 1800's when modern fermentation techniques were developed by Kutzing and Pasteur.

In the late 1800's, fermentation ethanol was used in the United States for cooking, heating, and lighting because it provided clean and odorless fuel. Henry Ford built a Model A car in the early 1900's with an adjustable carburetor enabling the car to be powered by pure ethanol, gasoline, or any mixture of the two. By the 1930's, ethanol fuels were widely used in the United States and 40 other nations, and an estimated four million cars were powered by ethanol fuels in Europe (2).

With the advent of World War II and the subsequent scarcity of oil, there was even more reliance on ethanol fuels. The Germans powered their war machinery with ethanol derived mostly from potatoes when their oil supply was severed. Also, in the United States, whiskey distilleries and newly built ethanol facilities supplied ethanol for use in submarines, aircraft, and land vehicles. In addition, ethanol was used as a feedstock in the developing synthetic rubber industry. In 1944, U.S. ethanol production totaled 600 million gallons, half of which went for synthetic rubber (3).

After the war, many distilleries were dismantled or converted to beverage plants. Gasoline became plentiful and inexpensive, and industrial ethanol needs could easily be met by the new, more economically produced synthetic ethanol that was derived from ethylene. By 1949, only 10 percent of industrial ethanol was produced from grain (3). In 1979, industrial ethanol constituted over 60 percent (more than 300 million gallons per year) of the ethanol produced in the United States.

In the 1970's, there was a renewed interest in ethanol from biomass, sparked by concern about increased U.S. dependence on insecure foreign oil supplies and an interest in finding alternative uses for agriculture products. It was not until 1979, however, that this renewed interest resulted in any significant use of ethanol for motor fuel.

The Nebraska state legislature acted in 1971 to reduce the state's gasoline tax by 3 cents per gallon for fuels containing at least 10 percent agriculturally derived ethanol, but this had little impact on ethanol consumption. The Arab oil embargo in 1973-74 stimulated additional interest in ethanol as world crude oil prices suddenly increased by nearly 400 percent. In spite of this large increase in oil prices, economic studies showed that ethanol from biomass would not be economically viable without a large subsidy. However, support for using ethanol as a motor fuel continued to grow among agriculture states. Iowa provided an excise tax exemption for ethanol/gasoline blends and developed a marketing program. Illinois joined in support and conducted tests of these fuel blends in state vehicles. Fleet tests were performed in Nebraska and Iowa. Sales of ethanol on the market began in Illinois in January 1978, at three retail stations. By mid-1978 market sales began in Iowa, and in November 1978, 60,850 gallons of ethanol were sold as motor fuel in that state (3).

By late 1978 the grassroots support for ethanol resulted in congressional action. The Energy Tax Act of November 1978 provided that ethanol/gasoline blends were exempt from the 4-cents-per-gallon federal excise tax on motor fuel from 1 January 1979 through 1 October 1984. The exemption applied to blends containing at least 10 percent ethanol produced from other than petroleum, natural gas, or coal; the exemption had the effect of providing a subsidy for ethanol of 40 cents per gallon (4 cents for each one-tenth of a gallon of ethanol included in an ethanol/gasoline blend).

The interruption of crude oil exports by Iran in early 1979 led to serious gasoline shortages in the U.S. and an increase of over 100 percent in world crude oil prices. The gasoline shortages and rapid oil price increases created a sense of urgency for U.S. efforts to reduce dependence on foreign oil, and it was concluded that ethanol from biomass was the only alternative fuel that could provide a substitute for OPEC oil in the short-term. By mid-1979, ethanol/gasoline blends were sold in over 800 retail outlets in 28 states, and a large demand for ethanol developed.

The crisis atmosphere of 1979 resulted in a host of government actions (both federal and state) to encourage production of ethanol-for-fuel from biomass as rapidly as possible. These initiatives included exempting ethanol/gasoline blends from gasoline taxes by many states, extension of the federal excise tax exemption, and initiation of a variety of federal grant and loan guarantee programs.

The rapidly increasing gasoline prices and the tax exemptions for ethanol/gasoline blends induced additional firms to produce ethanol for fuel. The initial production came entirely from plants which had been producing ethanol for beverage or industrial uses. A wave of announcements of plans for new or expanded ethanol-for-fuel plants occurred after enactment of the Crude Oil Windfall Profits Tax in April 1980, which extended the 4-cents-per-gallon federal excise tax exemption for ethanol/gasoline blends from 1984 through 1992. Many other organizations indicated that they were studying plant feasibility or applying for government loans or loan guarantees for their plants. Hundreds of potential ethanol-for-fuel plants were in various stages of study or planning by mid-1980.

In January 1981, the Reagan Administration announced that it was proposing to cut back on financial assistance for ethanol production, as part of its efforts to curtail federal spending. The Administration proposed to rely primarily on the federal excise tax exemption to support ethanol-for-fuel production. This action, along with unusually high corn prices and a weak gasoline market, resulted in reconsideration of decisions to proceed with many projects. Construction was halted on some projects, some existing plants reduced ethanol production or decided not to start production, and many plans for new plants were put on hold pending further analysis or resolution of financing issues.

In addition to federal excise tax exemption, many states exempted ethanol-for-fuel from state taxes. In thirty-four states, ethanol-for-fuel was exempted from all or part of state fuel taxes. With lower grain prices in 1984, and state tax exemptions and federal tax exemptions, the ethanol-for-fuel industry has continued to grow.

2.2 ETHANOL-FOR-FUEL-INDUSTRY STATUS

2.2.1 1981 PRODUCTION LEVELS

The ethanol-for-fuel industry is defined as commercial-size facilities (capacity greater than one million gallons of anhydrous ethanol per year) which convert biomass (via fermentation) to ethanol for use as fuel. By September 1981, the ethanol-for-fuel industry was composed of 15 plants with a combined production capacity of about 164 million gallons of ethanol per year. These plants are presented in Table 2-1.

Eight of these plants are grassroots facilities, six were converted from beverage alcohol facilities, and the remaining plant is an industrial grade ethanol facility. A variety of feedstocks are used which include grain, grain-derived high fructose corn syrup (HFCS) from corn sweeteners, wood sugars from wood pulping operations, and cheese whey. All the facilities, with the exception of the plant which processes wood sugars, sell their by-products, either wet or dry, as livestock feed. The plant which processes wood sugars concentrates its by-product lignin stream and then sends it to a lignin processing facility.

Approximately 60 percent of the 1981 ethanol-for-fuel capacity is from former beverage distilleries or from expansion of facilities previously used for industrial, medical, or beverage alcohol production. Grains such as corn, wheat, and milo are the major feedstock and account for over 96 percent of the ethanol produced. Natural gas or oil is used as the heat source for most of the current ethanol-for-fuel plants, although there are plans to convert some plants to coal. The plants are dispersed around the country, but over two thirds of the capacity is located in the central region of the country.

2.2.2 1985 PRODUCTION LEVELS

By September 1985, 102 ethanol-for-fuel plants, each with a capacity of 1 million gallons per year or greater, were located in 31 states. Of these, 57 were operating and 45 non-operating. Total production capacity was approximately 3.6 billion liters per year (941 million gallons per year). Capacity of the 57 operating plants was 2.9 billion liters per year (764 million gallons per year) as shown in Table 2-2.

Production of ethanol for fuel had expanded rapidly as shown by the following yearly production figures. (37)

Table 2-1

ETHANOL-FOR-FUEL FACILITIES
(1981)

Plant Code	Capacity (MM gal/yr)	Location	Feedstock
A01	60	IL	HFCS*
A02	20	PA	Corn
A03	3	KS	Corn, Milo, Wheat
A04	10	IL	Corn
A05	3	IA	Milo
A06	3	AR	Corn
A07	2	WA	Wood Sugars
A08	1.2	AL	Corn
A09	1.2	NC	Corn, Milo
A10	2	WI	Cheese Whey
A11	1	WA	Corn, Potatoes
A12	1	SD	Corn
A13	2.5	IA	Corn
A14	8.6	GA	Corn
A15	45	IA	Corn

*High fructose corn syrup.

Table 2-2

ETHANOL-FOR-FUEL OPERATING PLANTS
(1985)

State	Location	(Thous. gal/yr)	Feedstock
Arkansas	Van Buren	3,000	Corn
California	Selma	10,000	Molasses
	Winters	1,000	Industrial Wastes
	Cucamonga	5,000	"
	Corona	2,000	Cheese Whey
Colorado	Golden	2,400	Brewery Condensate
	Monte Vista	4,000	Potato
Idaho	Heyburn	3,000	Potato Waste & Hulls
Illinois	Rockford	3,000	Corn
	Decatur	150,000	Cornstarch
	Peoria	90,000	Corn
	Pekin	70,000	Corn
	Batavia	2,000	Sugary Wastes
	Pekin	11,000	Corn
Indiana	South Bend	50,000	Corn
Iowa	Cedar Rapids	60,000	Corn
(476)	Muscatine	10,000	Corn
	Bonaparte	4,000	Corn
	Clinton	20,000	Corn
	Hamburg	5,000	Corn
	Elgin	1,500	Corn
Kansas	Atchison	6,000	Corn
	Garden City	1,750	Corn
Kentucky	Franklin	20,000	Corn
Louisiana	Jennings	25,000	Molasses
	Port Allen	4,000	Molasses
	Belle Chasse	7,000	Blackstrap Molasses
	Shrevport	2,000	Milo
Minnesota	Melrose	1,000	Cheese Whey
	Mankato	2,000	Hydrous Ethanol
Montana	Ringling	1,500	Barley
	Amsterdam	1,850	Barley
Nebraska	Roca	1,500	Milo
	Hastings	11,000	Corn
New Jersey	Windsor	1,000	Waste Sugar
New Mexico	Clovis	1,200	Milo
(594.8)	Clovis	1,500	Milo
	Tucumcari	4,500	Milo
North Dakota	Walahalla	11,200	Barley

Table 2-2 (Continued)

ETHANOL-FOR-FUEL OPERATING PLANTS (1985)

State	Location	(Thous. gal/yr)	Feedstock
Ohio	South Point	60,000	Corn
	Navarre	1,000	Agricultural Wastes
Oklahoma	Hydro	5,000	Milo
Pennsylvania	Wadsfordsburg	1,650	Corn
Tennessee	Loudon	40,000	Corn
Texas	Euless	5,000	Milo
Utah	Tremonton	2,500	Barley
Virginia	Reston	5,000	Hydrous Ethanol
	Charles City	6,000	Hydrous Ethanol
	Floyd	7,000	Hydrous Ethanol
	Nelson	2,600	Hydrous Ethanol
	New Church	1,600	Corn
	Chesapeake	6,600	Hydrous Ethanol
	Wilsons	1,000	Corn
	Charles City	1,650	Corn
Washington	Bellingham	2,500	Sulfite Waste Liquor
Wisconsin	Jim Falls	1,500	Corn
	Juneau	2,000	Cheese Whey

Year	Actual Production (In millions of gallons)
1979	20
1980	40
1981	75
1982	210
1983	375
1984	430
1985	625 (est. from 3 quarters)

2.2.3. PLANTS UNDER CONSTRUCTION (1981)

In 1981 35 ethanol-for-fuel plants were under construction; six of these plants were beverage plants undergoing conversion and the remaining 29 were grassroots facilities. Seventeen of the plants under construction were scheduled to be on-line by 1980, the rest were scheduled to be operational by 1982. These plants are summarized in Table 2-3.

The total capacity for these 35 plants was about 705 million gallons per year, over one-third (259 million gallons) will be produced by converted beverage alcohol facilities. Approximately 81 percent of the ethanol will come from facilities which produce 20 million gallons per year or more. The size distribution for plants under construction is presented below.

Range (million gallons/year)	Number of Plants
1-5	16
6-15	10
16-35	4
36-75	3
>75	2

Grains such as corn, wheat, milo, and barley are the predominant feedstock and accounting for almost 94 percent of the designed ethanol production. Sugar feedstocks such as sugarcane, sugar beets, and molasses were projected to provide about seven percent of the ethanol. Potatoes were projected to provide less than 1 percent of the ethanol from plants under construction.

The plants were to be located in 20 states and dispersed in almost all regions of the country. Almost half of the capacity for plants under construction in 1981 were located in the midwest.

2.2.4 PLANTS UNDER CONSTRUCTION (1985)

In September 1985, 15 ethanol-for-fuel plants were under construction. These facilities have a combined capacity of 833 million liters per year (220 million gallons per year). All

Table 2-3

PLANTS UNDER CONSTRUCTION
(1981)

Code No.	Location	Ethanol Production (MM gal/yr)	Feedstock	On-Line Date
C01*	IL	190	HFCS	Late 1981
C02	LA	120	Corn	Mid 1982
C03	OH	60	Corn	Mid 1982
C04	IL	60	Corn	
C05	GA	10.5	Corn	
C06	IA	10	Corn	
C07	TN	40	HFCS	1982
C08	LA	34.6	Sugarcane, Molasses	1982
C09**	IL	21.5	Corn	Mid 1981
C10	KY	21	Corn	Jan. 1982
C11	CO	8.5	Grain, Sugar Beets	
C12	NC	25	Corn	
C13	OK	12	Milo	June 1981
C14	SC	11	Corn	Late 1982
C15	ID	4	Corn	
C16**	IN	8	Corn	1981
C17**	KY	8	Corn	
C18	IN	6	Corn	Spring 1982

*Expansion of plant A01.
**Converted beverage alcohol facilities.

Table 2-3 (Continued)

PLANTS UNDER CONSTRUCTION
(1981)

Code No.	Location	Ethanol Production (MM gal/yr)	Feedstock	On-Line Date
C19**	KY	6	Grain	1981
C20**	KY	5.5	Corn	1981
C21	ND	3.5	Potatoes	
C22	KS	6	Milo	
C23	MN	4	Wheat, Barley	Early 1982
C24	KY	3.5	Corn	1981
C25	CO	3	Milo	1981
C26	IA	5.4	Corn	
C27	MD	2.5	Corn, Barley	Nov. 1981
C28	IA	2.5	Corn	--
C29	CO	2.5	Barley, Potatoes	Jan. 1982
C30	IN	2	Corn	1981
C31	OR	1.8	Grain	1981
C32	WI	1.5	Corn, Potatoes	1981
C33	OH	1.2	Corn	1981
C34	WI	1	Corn	1981
C35	WA	1	Corn	--

**Converted beverage alcohol facility.

of these new plants are grass roots facilities. Plants are located in 12 states as shown in Table 2-4. Corn and other grains will be the predominant feedstock of these new facilities with 96 percent of production coming from grains. The other 4 percent will be produced from other feedstocks, including cheese whey. One plant will be operating to dehydrate hydrous ethanol.

2.2.5 PROPOSED PLANTS (1981)

In 1981 there were 42 proposed ethanol-for-fuel plants. These are presented in Table 2-5. Two to three years are needed for the construction of a facility. Site location, funding, and economic incentives determine how many of these plants will actually be built. With the interest in ethanol fuels and availability of various feedstocks, in 1981 it was expected that many of these plants would be on-line by December 1985. The combined production capacity of the proposed plants is about 980 million gallons per year, with the plants falling into the following ranges:

Range (million gallons/year)	Number of Plants
1-5	7
6-15	11
16-39	17
40-75	6
>75	1

The feedstocks for these proposed plants are summarized below:

Feedstock	No. of Plants*	% Total Capacity
Grains (Corn, Wheat, Barley, Milo)	34	83.1
Sugars (Sugarcane, Sweet Sorghum, Sugar Beets, Molasses, Sweet Potatoes, Cheese Whey)	3	8.2
Potatoes	2	0.4
Unknown	5	8.3

*Note: Some facilities plan to use more than one type of feedstock.

Table 2-4

ETHANOL-FOR-FUEL PLANTS UNDER CONSTRUCTION (September 1985)*

State	Company	Capacity (Thous. gal/yr)	Feedstock
Alaska	Diamond R	1,200	Barley
California	United Energy (Barrego)	1,500	Corn,
	United Energy (Yermo)	1,500	Corn, molasses
Iowa	Archer Daniels Midland	70,000	Corn
Illinois	Archer Daniels Midland	50,000	Corn
	Agmont, Inc.	2,500	Corn, wheat
Indiana	Solar Alcohol Energy, Inc.	1,000	Corn
Louisiana	Mississippi River Alcohol Co.	42,000	Corn
Minnesota	Minnesota Dairy Tech.	2,300	Cheese whey
N. Dakota	Alchem Limited	4,500	Barley, potato
New Mexico	Aurora Rresources, Inc.	2,000	Milo
S. Carolina	Agripin	9,000	Corn
Tennessee	Tennol Energy Company	25,000	Corn, Milo
Virginia	Newport News Energy Assn.	1,650	Corn, Barley, Milo
	American Fuel Trading Co.	6,000	Hydrous Ethanol

*Reference (37)

Table 2-5

PROPOSED PLANTS
(1981)

Code No.	Location	Ethanol Production (gal/yr x 10^6)	Feedstock
D01	IA	216	Corn
D02	PA	63	Corn
D03	IN	50	Corn
D04	VA	50	Corn
D05	LA	40	Corn, Molasses
D06	LA	40	Sugar
D07	IN	36	Corn
D08	CO	30	Unknown
D09	ME	25	Corn
D10	TN	25	Corn
D11	TX	22	Milo
D12	MI	20	Corn
D13	MI	20	Corn
D14	PA	20	Corn
D15	SC	20	Corn
D16	IN	20	Grain
D17	IA	20	Corn
D18	IA	20	Corn
D19	LA	20	Sugar Cane, Sorghum, Corn Molasses
D20	SC	20	Unknown

Table 2-5 (Continued)

PROPOSED PLANTS
(1981)

Code No.	Location	Ethanol Production (gal/yr x 10^6)	Feedstock
D21	KS	18	Corn, Milo
D22	MD	15	Corn
D23	MN	15	Grain
D24	NB	15	Grain
D25	IL	14.3	Corn
D26	KS	12.5	Corn
D27	MT	10.5	Unknown
D28	IL	10.5	Unknown
D29	IL	10.5	Unknown
D30	KY	10	Corn
D31	WA	10	Corn
D32	MI	10	Corn
D33	VA	10	Grain
D34	MO	10	Corn
D35	IA	10	Corn
D36	ID	5	Wheat, Barley, Potatoes
D37	FL	5	Corn, Milo
D38	MN	4	Barley, Wheat
D39	GA	2.5	Corn
D40	CO	2.5	Potatoes, Barley
D41	GA	2	Grain
D42	NB	1	Corn

2.2.6 PROPOSED PLANTS (1985)

In 1985 there were 38 proposed ethanol-for-fuel plants in the U.S. (37) These 38 plants represent a capacity of nearly 2.2 billion liters per year (593 million gallons per year). Approximately one quarter of these plants are expected to enter construction. The proposed plants (1985) are listed by state in Table 2-6.

Another 36 ethanol-for-fuel projects are "on hold." These 36 plants represent over 1.9 billion liters per year (508 million gallons per year) production. (37) The probability of any of these facilities reaching construction is very low. (37)

2.2.7 PROJECTED PRODUCTION

A study conducted by the Department of Energy in 1979 estimated the availability of surplus agricultural feedstocks and biomass sources for conversion to ethanol. Based on this information, the maximum amount of ethanol which can be produced from these sources is presented in Table 2-7. To calculate these projections, the DOE study assumed the following percentages of feedstocks to be available for conversion to ethanol: cheese whey, 80 percent; citrus wastes, 80 percent; corn, 80 percent; wheat, 80 percent; sugar cane, 100 percent; and sweet sorghum, 100 percent. The study also considered sweet sorghum to be a better feedstock than corn because it is cheaper, has a higher yield, and requires less feedstock processing. Therefore, this study assumed that 14 million acres of pastural or set-aside land would be converted to sweet sorghum production by the year 2000, allowing the elimination of corn as a feedstock. In addition, it should be noted that the projections for wood and agricultural residues depend on the development of appropriate technology.

Geographic Distribution

Figure 2-1 presents the geographic distribution by EPA regions of existing ethanol-for-fuel plants which were existing in 1981 or were under construction and proposed for construction. As this figure shows, Regions 4, 5, 6, and 7 were projected to contain 73 percent of the facilities and 83 percent of the total capacity.

Figure 2-2 shows the same projected plants by state. Thirty-three states were projected to have at least one ethanol-for-fuel facility. Six states including Colorado, Iowa, Illinois, Indiana, Louisiana, and Kentucky were projected to have five or more facilities. Table 2-8 shows the 1985 status by state, showing the number of existing plants and the number of operating plants.

Table 2-6

ETHANOL-FOR-FUEL PLANTS PROPOSED
(September 1985)

State	Location	Capacity (Thous. gal/yr)	Feedstock
Alabama	Decatur	25,000	Corn
Florida	Pensacola	3,000	Milo
Iowa	Ames	23,000	Corn
	Eddyville	6,000	Corn
	Ethersville	6,000	Corn
	Spencer	10,000	Corn
Illinois	Argo	135,000	Corn
	Piatt County	6,500	Corn, Milo
Kansas	Liberal	6,000	Corn
Kentucky	Calvert City	20,000	Corn
Louisiana	Baton Rouge	10,000	Corn
	Jonesville	5,000	Molasses, Sugar
	New Iberia	49,000	Sugar cane, Sorghum
	New Orleans	35,000	Corn
	Vidalia	12,000	Corn
Maine	Auburn	15,000	Corn
Minnesota	Appleton	3,150	Corn
	Clarkfield	5,000	Corn
	Glenville	10,000	Corn
	Mankato	20,000	Corn
	Marshall	10,000	Corn
Montana	Billings	4,000	Wheat
	Hardin	10,000	Barley
North Carolina	Lumberton	1,500	Corn
Nebraska	Benkleman	30,000	Corn, Milo
	Blair	16,500	Corn
	Lincoln	12,000	Corn
	Sidney	18,000	Wheat
	Winnebago	10,000	Corn

Table 2-6 (Continued)

ETHANOL-FOR-FUEL PLANTS PROPOSED
(September 1985)

State	Location	Capacity (Thous. gal/yr)	Feedstock
New Jersey	Carney's Point	10,000	Corn
New Mexico	Las Cruces	10,000	Corn, Milo
	Lovington	12,000	Milo, Wheat
Oregon	Klamath	10,000	Corn
Texas	Hereford	7,000	Corn
Utah	Salt Lake City	2,000	Wheat
Virginia	Norfolk	10,000	Corn, Milo
	Stony Creek	10,000	Corn
	Taskey	5,000	--

Table 2-7

PROJECTED MAXIMUM ETHANOL PRODUCTION FROM U.S. BIOMASS RESOURCES

[Million Gallons Per Year]

	1985	1990	2000
Wood	21,800	20,200	25,800
Agricultural Residues	10,300	11,300	13,100
Grains:			
Corn	2,100	900	--
Wheat	1,400	1,600	2,000
Grain Sorghum	300	300	300
Total Grains	3,800	2,800	2,300
Sugars:			
Cane	200	700	700
Sweet Sorghum	200	3,000	8,300
Total Sugars	400	3,700	9,000
Municipal Solid Waste	2,300	2,500	2,900
Food Processing Wastes:			
Citrus	200	300	400
Cheese	100	100	200
All Other	300	300	300
Total Processing Wastes	600	700	900
TOTAL	39,200	41,200	54,000

Reference 3.

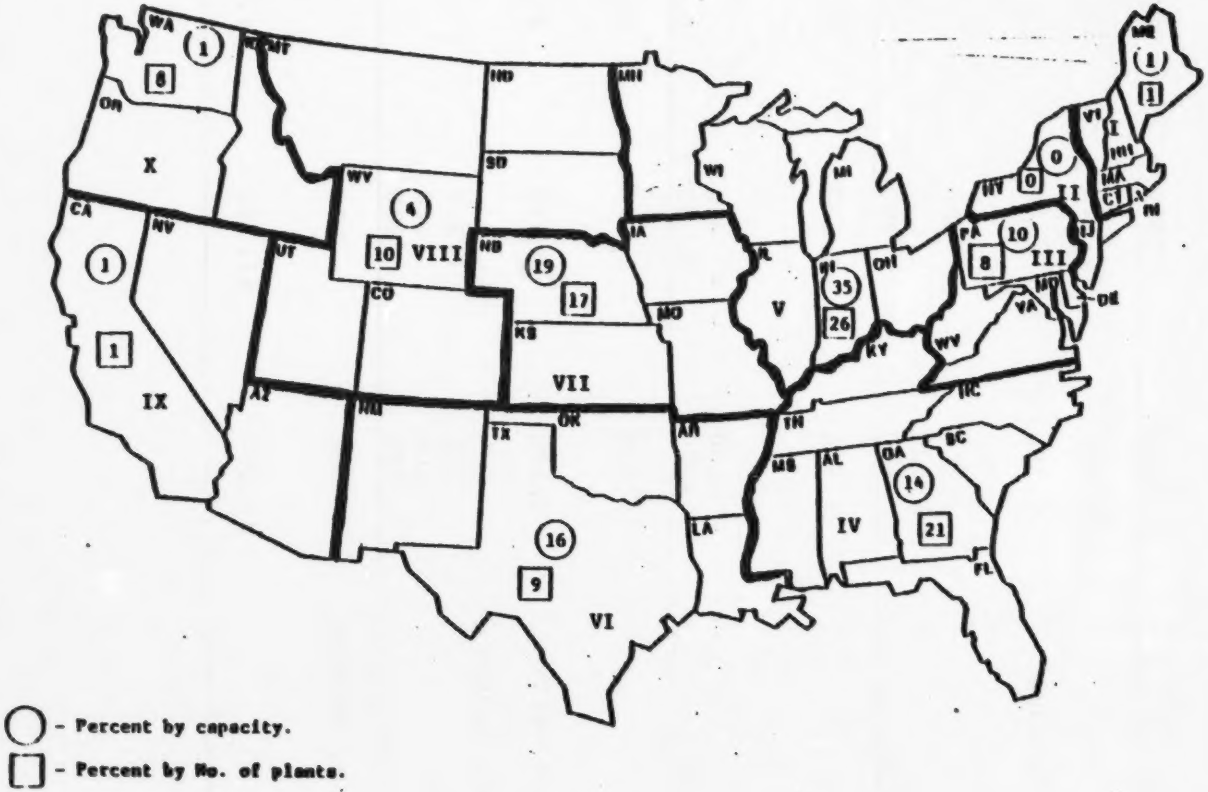
WA
1
8
OR
X
MT
ID
WY
4
10
VIII
ND
SD
NB
19
17
MN
WI
MI
IA
CA
1
1
IX
NV
UT
CO
KS
VII
MO
IL
V
IN
35
26
OH
KY
PA
10
8
III
NY
0
0
II
VT
NH
ME
1
1
I
MA
CT
RI
NJ
DE
MD
VA
WV
AZ
NM
TX
OK
16
9
VI
AR
LA
TN
MS
AL
IV
GA
14
21
SC
NC
FL
○ - Percent by capacity.
□ - Percent by No. of plants.

Figure 2-1

PROJECTED GEOGRAPHIC DISTRIBUTION OF ETHANOL-FOR-FUEL PLANTS IN 1990 BY U.S. EPA REGIONS

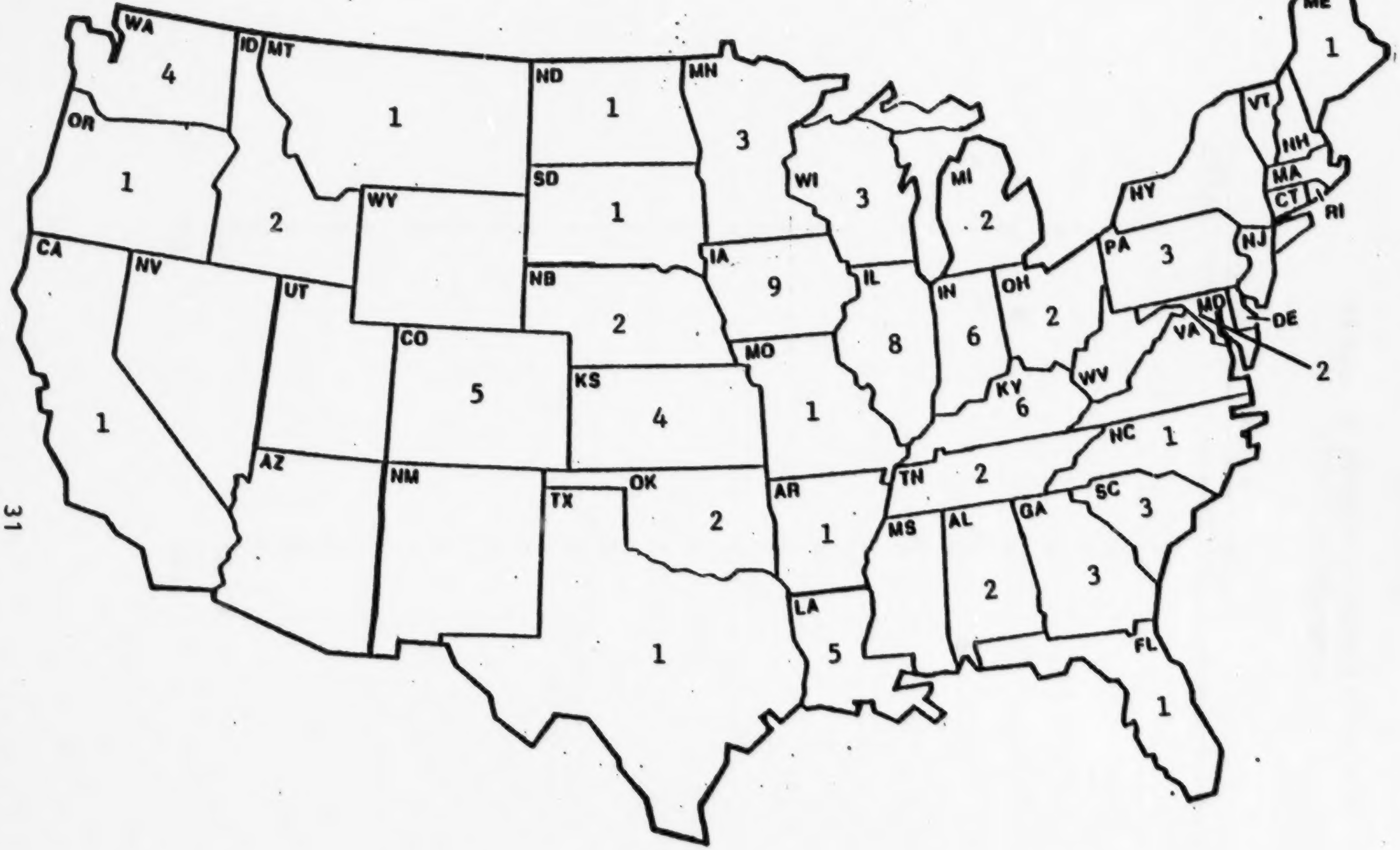
WA 4
ID
MT 1
ND 1
MN 3
OR 1
SD 1
WI 3
MI 2
ME 1
VT
NH
MA
CT
RI
NY
WY
CA 1
NV
UT
IA 9
IL 8
IN 6
OH 2
PA 3
NJ
MD
DE
VA
2
NB 2
CO 5
MO 1
KS 4
KY 6
WV
NC 1
AZ
NM
TX 1
OK 2
AR 1
TN 2
SC 3
MS
AL 2
GA 3
LA 5
FL 1
ID 2

Figure 2-2

PROJECTED GEOGRAPHIC DISTRIBUTION OF ETHANOL-FOR-FUEL PLANTS BY STATE

Table 2-8

ETHANOL-FOR-FUEL PLANTS BY STATE
(September 1985)

State	Number of Plants	
	Total	Operating
Alabama	1	0
Arkansas	1	1
California	6	4
Colorado	5	2
Florida	2	0
Georgia	2	0
Idaho	3	1
Illinois	6	6
Indiana	2	1
Iowa	9	5
Kansas	3	2
Kentucky	4	1
Louisiana	6	4
Maryland	1	0
Michigan	2	0
Minnesota	5	3
Montana	2	2
North Dakota	1	1
Nebraska	4	2
New Jersey	1	1
New Mexico	7	3
Ohio	2	2
Oklahoma	1	1
Pennsylvania	2	1
South Dakota	2	0
Tennessee	1	1
Texas	3	1
Utah	2	1
Virginia	9	8
Washington	3	1
Wisconsin	4	2
TOTAL	102	57

Source: (37)

Future Ethanol-for-Fuel Processes

In addition to the feedstocks in use in the ethanol- for-fuel industry, it is projected that sugar cane, sweet sorghum, sugar beets, cane molasses, citrus molasses, cellulose, cheese whey, and potatoes may be used to provide ethanol for fuel. Despite the feedstock used, all new ethanol-for-fuel plants constructed in the near future are expected to use fermentation, distillation, and dehydration systems similar to those for existing ethanol-for-fuel plants. This is due to the fact that all feedstocks enter the fermenter as simple sugars regardless of their original form. Nonfermentable matter (e.g., protein, fiber, lignin) is routed to by-product processing, thus providing an ethanol/water feed to distillation and dehydration which is independent of the feedstock.

Feedstock preparation techniques, on the other hand, will vary depending on the type of biomass used for conversion. Over the years, various methods of grinding, pulverizing, and mashing have been specially developed for different feedstocks. Also, by-product recovery systems, although analogous, will vary according to the desired form (i.e., dry, moist, or liquid) and marketability of the recovered by-product.

2.3 ETHANOL-FOR-FUEL PROCESS DESCRIPTION

In the United States, ethanol for beverage purposes must be derived entirely from the fermentation of starch or sugar feedstocks. However, industrial- or fuel-grade ethanol can be made via fermentation or synthesized from ethylene, a gas derived from petroleum. Synthetic ethanol is not considered in this document. Only those facilities producing ethanol which is derived from renewable biomass feedstocks are defined as part of this industry.

All fermentation ethanol plants employ four basic processes: feedstock preparation, fermentation, distillation, and dehydration. A fifth process, by-product recovery, is also possible, but not necessarily included in all ethanol-for-fuel plants. Slight variations within each of the first four processes are available; however, differences in fermentation, distillation, and dehydration do not result in significant changes in the quality or amount of emissions and effluents. Those steps which may affect the characteristics of the wastes generated include the feedstock preparation technique and the inclusion of the fifth process, by-product recovery.

2.3.1 FEEDSTOCK PREPARATION

Feedstock preparation includes all steps in converting the raw material (i.e., corn or wood chips) to a saccharified mash which enters the fermenters. Depending on the feedstock, different methods of preparing a saccharified mash and for removing valuable by-products from the feedstocks, such as germ (protein) or lignin (cellulosic material), are available. The feedstock preparation techniques in use in the existing ethanol-for-fuel industry include dry milling, wet milling, wood sugar preparation, and cheese whey preparation.

Processing of Grain Feedstocks

The incoming grain contains considerable amounts of dirt and extraneous matter such as stover, cobs, twigs, sand, tramp metal, mold clumps, and stones. Therefore, the grain is first cleaned and rough ground to remove the foreign matter. Large amounts of particulate emissions occur from grain receiving, cleaning, and conveying in addition to storage, milling, and processing of the grain. The majority of the emissions are fugitive and arise primarily from raw material handling. After preliminary cleaning and grinding, two methods are available for preparing the grain for fermentation: dry milling and wet milling.

Dry Milling. In the dry milling process, the grain is bar milled or hammer milled to form a fine meal. Milling breaks the outer cellulosic wall around each kernel to expose more starch surface to the action of cooking and conversion.

Water is added to the milled grain and the suspension is fed into a cooker. Cooking may be carried out under pressurized or atmospheric conditions in either batch or continuous processes. Steam is injected during cooking to raise the temperature which aids in solubilizing and gelatinizing the mash, thus forming a more suitable substrate for enzymatic hydrolysis (biological breakdown) of starches into sugars.

After cooking, the mash is cooled to about 63°C and ground barley malt or fungal amylase is added to convert the solubilized starches by enzyme action into component five and six carbon sugars. This conversion may take place in a separate vessel called a "converter" in order to free the cooker for the next batch. The slurry, at this point called "mash," is further cooled via vacuum or tubular heat exchangers to about 27°C and then pumped to the fermenters.

Wastes from the mashing process consist of condensate from pressure cookers and vacuum coolers in addition to residual material from vessel cleanup. For plants operating in this mode, the load comprises about 12 percent of the total plant waste. For plants with atmospheric cookers and shell and tube mash coolers, the load would be lower.

Wet Milling. Another method of grain preparation used for corn is referred to as wet milling. In this process, the corn is first steeped in a dilute aqueous solution of sulfur dioxide to soften the kernels and cob (if whole corn is used) and to remove soluble materials. The sulfur dioxide extract is collected and concentrated to produce a product which is sold for fermentation media and animal feed.

The softened kernels are then coarse-milled to loosen the oil-containing germ, then washed and dried. After drying, the germ is further processed by solvent extraction to yield the desirable corn oil and a residual cake which is a valuable animal feed material. The material remaining after removal of the germ passes through successive milling, screening, and washing to remove the hull fiber, which is dried and also used in animal feed formulations.

At this point, a slurry which consists of a mixture of starch and protein remains. This mixture is separated centrifugally to produce the protein fraction that constitutes a valuable, high-protein corn gluten by-product. The remaining fraction, which is starch, is obtained from the centrifuges as a concentrated slurry containing upwards of 40 percent solids.

The starch stream is then fed into a converter for enzymatic or acid hydrolysis to fermentable sugars. Vacuum or tubular heat exchangers may be used to cool the saccharified mash before entering the fermenters.

The wastes generated from the corn wet milling process include the water removed from the sulfur dioxide extract during concentration, the numerous wash waters, and the condensate from the vacuum coolers if this equipment is used.

In cases where corn wet milling is used in conjunction with another process (e.g., corn sweetener), the wastes generated from corn wet milling were not considered in ethanol-for-fuel industry since corn wet milling will be covered as part of the food industry.

Wood Sugar Preparation

It is possible to produce fermentable sugars from wood by treating it with sulfuric acid, lime rock, and caustic soda. This process is one form of pulping in which the resulting fibrous cellulosic material can be separated from a solution of calcium lignosulfate and wood sugars by filtration or centrifugation.

The lignin/sugar solution is referred to as spent sulfite liquor (SSL) and is usually concentrated in evaporators prior to further processing. Nearly all pulp mills that employ this technique either burn or recover the lignin from the SSL; however, one pulp mill routes this SSL stream to an ethanol plant which removes the sugars (via fermentation) before recovering the lignin.

The SSL stream is steam stripped to remove volatile sulfur compounds and cooled using noncontact heat exchangers. The stream is then neutralized to a pH of 4.3 and supplemented with aqueous ammonia to satisfy the nutritional requirements of the yeast prior to fermentation.

Excluding the wastes generated from pulping operations, the wastes generated from this process include the evaporator condensate and the overhead stripper condensate containing the soluble sulfur compounds.

Cheese Whey Preparation

Cheese whey is currently being used at one plant to produce 96.5 percent ethanol. The ethanol is sold to another plant which dehydrates the ethanol for its eventual use as a fuel. The use of cheese whey as a feedstock has significantly reduced the environmental impact of discharging cheese whey to the local receiving water or wastewater treatment plant (4).

The preparation of cheese whey for use in ethanol production is shown in Figure 2-3. The whey concentrate as received contains 35 to 40 percent total solids and a lactose content of 35 to 38 percent (5). After pasteurization, the cheese whey enters a solid bowl centrifuge which removes the whey protein. The whey protein is a valuable by-product used in food additives such as casein. The supernatant, a 75 percent lactose stream, enters the fermenters.

The necessity of maintaining high-purity surroundings for food additive processing requires numerous system cleanings. This is the only waste stream generated by this process.

2.3.2 FERMENTATION

The biological conversion of the saccharified mash by yeast for the production of ethanol can be rendered in a continuous or batch fermentation process. The grain and wood sugars are converted into ethanol and carbon dioxide according to the following chemical equation:

$$C_6H_{12}O_6 \xrightarrow[\text{yeast}]{} 2C_2H_5OH + 2CO_2$$

Other reactions also occur producing small quantities of acetic acid, aldehydes, and longer chain alcohols often referred to as fusel oils. These processes are well documented in most biochemistry text books.

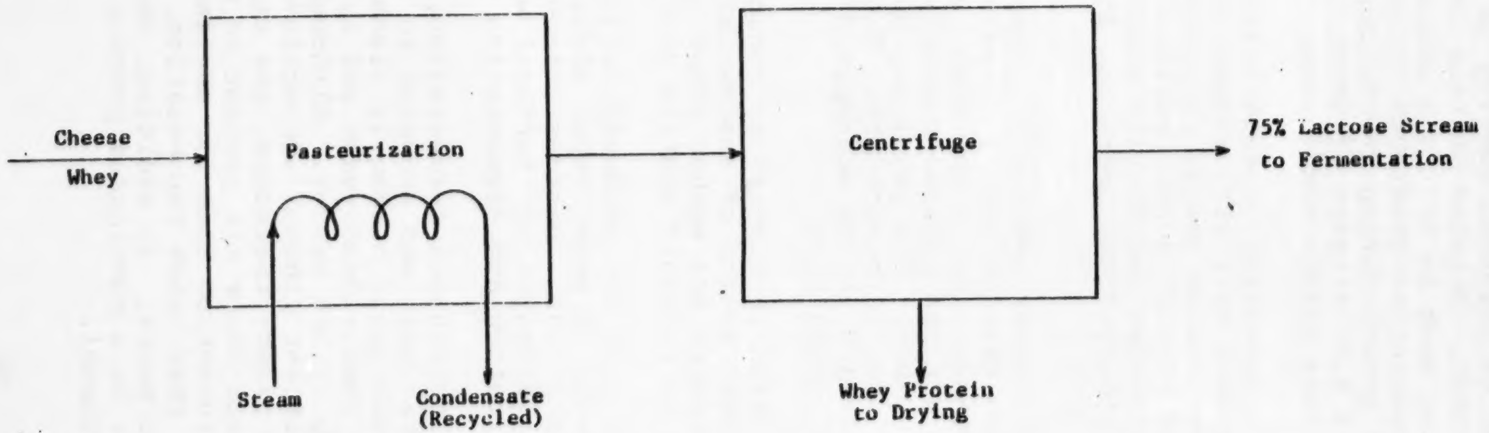
Cheese
Whey
Pasteurization
Steam
Condensate
(Recycled)
Centrifuge
Whey Protein
to Drying
75% Lactose Stream
to Fermentation

Figure 2-3
PROCESS DIAGRAM FOR CHEESE WHEY PREPARATION

Continuous and batch fermentation processes require temperature control, agitation, and pH adjustment. Fermentation is an exothermic process, and external or internal cooling is usually employed for temperature control. Related to this is the necessity to agitate the fermenting mash to maintain homogenous temperature and ethanol concentration gradients throughout the vessel. To retard bacterial growth during fermentation, the pH is controlled between 4.5 and 5.0; strains of yeast used have been developed to tolerate these acidic conditions.

Depending on the choice of fermentation process (batch or continuous), the fermented mash will vary with respect to yeast reclamation and recycle, fermentation vessel residence time, live yeast concentration, and ethanol concentration. These four parameters are closely interrelated and require special attention for the maintenance of steady-state operation in continuous fermentation.

Batch Fermentation. Batch processes add predetermined amounts of pure cultured yeast to each reactor vessel containing the saccharified mash. The residence time of the mash varies from 60 to 72 hours, resulting in a final ethanol concentration of approximately 10 percent by volume. The yeast may be removed by centrifugation and sold as a protein by-product. The relative ease of batch fermentation has led to its widespread use in the beverage and ethanol-for-fuel industries.

Water usage in batch fermentation is limited to noncontact cooling in the fermenters. The only source of wastewater is from fermenter washing. The fermenters are washed after each batch with steam and disinfectants to maintain sterile conditions.

Large quantities of carbon dioxide are produced during fermentation which contain small amounts of water vapor along with traces of volatile organic compounds. Besides ethanol, these organic compounds include acetaldehyde and furfural which are by-products of the saccharification and fermentation reactions.

Continuous Fermentation. In continuous fermentation, the yeast is separated from the fermented mash and recycled to the fermenters. A portion of the recycle yeast stream is discharged or recovered as a by-product to remove dead yeast and to prevent contaminants from building up in the system. Although concentrations of 10 to 12 percent ethanol are achievable, this level of ethanol is toxic to yeast; therefore, the ethanol concentration is generally kept below six percent to maintain a high yeast population. The retention time for continuous fermentation is much shorter than batch fermentation, usually between eight and twenty-four hours. In addition, the yeast population density is greater in a continuous process to enhance the conversion of sugar to ethanol.

Only two ethanol facilities in the United States currently use continuous fermentation; these plants also provide anhydrous ethanol for fuel. Plant A01 uses both batch fermenters and continuous fermenters. Plant A07 conducts a type of continuous fermentation in which a series of well-mixed reaction vessels are used with a total retention time of eight to ten hours.

As in batch fermentation, continuous fermentation produces large quantities of carbon dioxide containing traces of organic compounds and water usage in continuous fermentation is restricted to noncontact cooling water. Unlike batch fermentation, continuous fermenters are cleaned infrequently; this results in a reduction of wastewater.

In both fermentation processes, the fermented mash, known as "beer," is sent into a beer well en route to the beer still. The beer well is a holding tank for the fermenters which ensures continuous feed to the beer still and allows some settling of solids out of the mash.

2.3.3 DISTILLATION

In distillation, the solids and most of the water is separated from the ethanol. The process variations which occur at this point are no longer a function of the feedstock but of the ultimate product quality desired and age of the plant. For example, those plants which produce potable ethanol as well as fuel-grade ethanol include additional purification steps in their distillation trains to remove nearly all impurities (e.g., fusel oils and aldehydes). This type of distillation sequence is referred to as a conventional system. A second type of distillation train is used by former beverage alcohol producers who have converted their facilities to produce only ethanol-for-fuel. In these converted facilities, purification columns are eliminated in response to relaxed purity requirements for fuel blends. Finally, a third distillation scenario is depicted by grassroots ethanol-for-fuel facilities that are designed to minimize energy requirements and wastewater generation.

Conventional Distillation

Prior to entering the beer still, the fermented mash may enter a degasser drum where the dissolved carbon dioxide is flashed off. The amount of carbon dioxide released here is comparatively small and is not recovered. The fermented mash, containing 10 to 12 percent ethanol, is then preheated by the beer still overhead heat exchanger before entering the column. Once the mash enters the beer still, the solids and much of the water are separated from the ethanol.

Live steam is injected at the base of the column to strip the ethanol from the fermented mash introduced near the top of the still. The vapor leaving the top of the still is condensed and forms the product, an 80 percent ethanol solution containing some impurities. The discharge from the base of the column contains the soluble and suspended substances carried through the process. Depending on the feedstock and its preparation technique, the beer still bottom stream may contain many useful by-products.

The purification columns following the beer still remove the aldehydes, fusel oils, and water, while concentrating the ethanol. Figure 2-4 illustrates a typical column arrangement.

The overhead beer still stream containing the ethanol enters a solvent extractor which functions as an extractive distillation column. The water injected into this column helps to separate the fusel oils and aldehydes from the ethanol and may be fresh or recycled from another part of the plant. The water and ethanol exit the bottom of the column with an ethanol concentration of 10 to 20 percent. The more volatile aldehydes and fusel oils leave the column at the top and just below the feed tray, respectively.

The aldehyde stream from the solvent extractor is sent to the aldehyde concentrating column along with the overhead stream from the rectifier, which is also high in aldehydes concentration. The aldehydes exit the top of the concentrating column; the bottom stream, containing some ethanol from the rectifier and fusel oils from the solvent extractor, is recycled to the solvent extraction column.

The fusel oil-rich stream removed from the solvent extractor enters the fusel oil column where they are removed in a concentrated stream overhead. The water which enters the fusel oil column leaves the bottom of the column and is pumped to the wastewater treatment plant.

The rectifier receives the dilute ethanol stream (containing small quantities of aldehydes) from the solvent extractor. The aldehydes are removed from the top and sent to the aldehyde concentrating column, while the binary azeotrope of five percent water and 95 percent ethanol is removed near the top of the rectifying column. The ethanol stream from the rectifier is then routed to the dehydration system. The rectifier bottoms, which is relatively pure water, can be discharged to the wastewater treatment system or recycled to the solvent extractor.

Wastewaters from this multi-column process comprise two to four percent of the total plant BOD load and fifteen to thirty percent of the total wastewater volume, depending on whether or not the rectifier bottoms are recycled. This does not include the wastewater from beer still bottoms which is routed to by-product

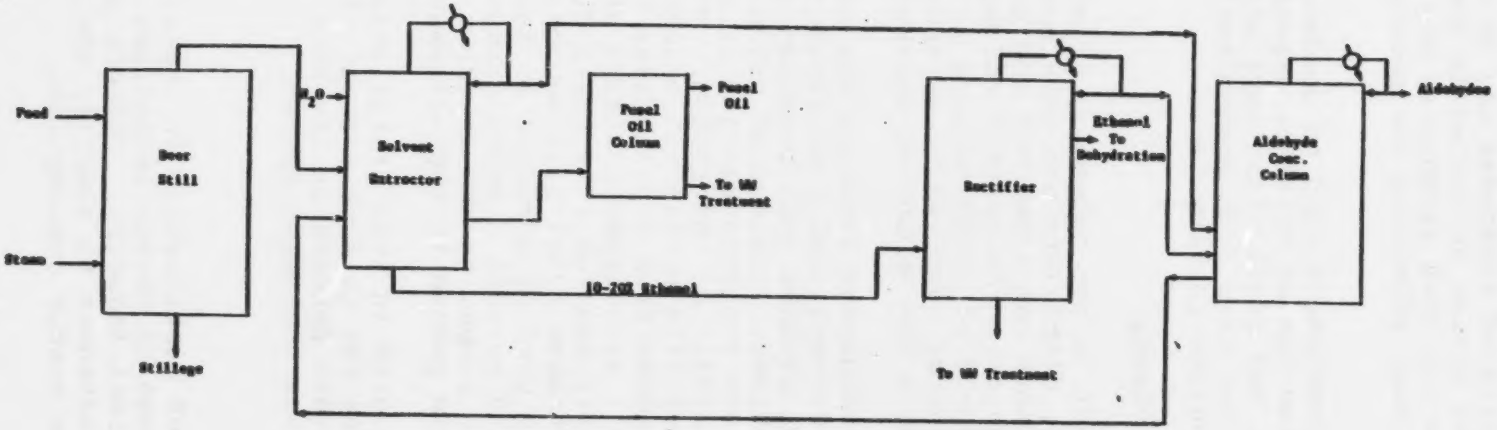
Feed
Steam
Beer Still
Stillage
H_2O
Solvent Extractor
Fusel Oil Column
Fusel Oil
To WW Treatment
10-20% Ethanol
Rectifier
Ethanol To Dehydration
To WW Treatment
Aldehyde Conc. Column
Aldehydes

Figure 2-4
CONVENTIONAL DISTILLATION

processing. Concentrated aldehydes may be discharged to the wastewater treatment system or burned as fuel. Fusel oils, which are less volatile than aldehydes, may be combined with the ethanol product without affecting the performance of fuel blends.

Vents on overhead condensers used to condense the distillation column vapors are sources of volatile organic emissions such as ethanol, aldehydes, and fusel oils (amyl alcohols). Although these vent streams may have high concentrations of these compounds, the total volume is very low.

Converted Beverage Plants

A high-purity product is not necessary if ethanol is to be used for fuel; therefore, distillers who have converted their beverage alcohol plants can eliminate the solvent extraction column and the aldehyde concentration column as illustrated in Figure 2-5. The removal of these columns from the distillation train reduces the energy required to separate the ethanol from water and also reduces the amount of wastewater generated.

In this method, the degasser drum and the beer still function in the same manner as conventional distillation schemes with the concentrated ethanol product sent overhead and the solids removed from the bottoms. Instead of being routed to a solvent extraction column, the top ethanol-rich stream now enters the rectifier near the middle of the column. To prevent the accumulation of fusel oils within the column, a sidestream rich in fusel oils is removed from a plate near the top of the column. The fusel oil sidestream contains ethanol as well as water which is usually removed in a fusel oil concentrating column. The concentrated fusel oils may be blended back into the final product or used as a source of fuel for the distillation columns. A 96 percent ethanol stream leaves the top of the rectifier and is pumped to the dehydration system. The rectifier bottoms are pumped to the wastewater treatment plant.

The wastewater generated in this distillation scheme is estimated to comprise two to four percent of the total BOD plant load and ten to fifteen percent of the total volume of wastewater sent to the treatment system.

Current Designs

The widespread use of distillation in the oil industry has led to technology advances in design techniques which are applicable to the ethanol-for-fuel industry. Ethanol plants of the future will utilize these advances to simplify the necessary separation processes and reduce energy consumption.

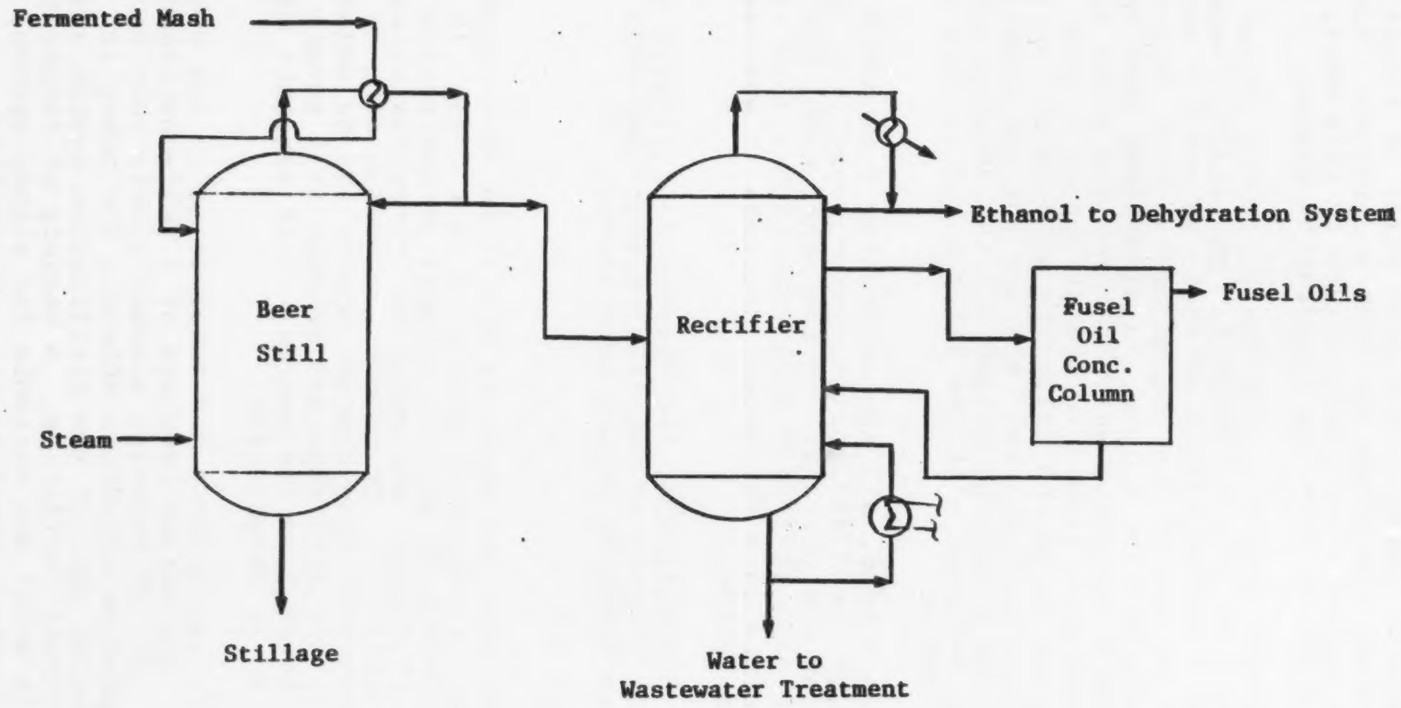
Fermented Mash
Beer
Still
Steam
Stillage
Rectifier
Ethanol to Dehydration System
Fusel
Oil
Conc.
Column
Fusel Oils
Water to
Wastewater Treatment

Figure 2-5

CONVERTED BEVERAGE PLANT

Figure 2-6 illustrates the basic features of an ethanol-for-fuel distillation design which might be found in a grassroots facility. The system is similar to the two-column converted beverage alcohol plant. However, the beer still no longer receives its heat from live steam but from a reboiler. Also, the second column, called a stripping column in this case, receives a recycled stream from the dehydration system.

The beer still overhead stream enters the stripping column containing approximately 50 percent ethanol. The ethanol/water azeotrope occurs at a concentration of 95 to 96 percent ethanol. This stream leaves the top of the column and is then condensed and pumped to the dehydration column. A sidestream near the top of the column enters a separator which removes the fusel oils and recycles the remaining liquid to the stripping column. The remaining input to the stripping column is an ethanol/water stream from the dehydration system. Most of the dehydration agent which enters the stripping column via the dehydration recycle stream goes overhead with the ethanol and is sent back to the dehydration system.

In this distillation scheme, all the wastewater from dehydration is discharged through the distillation system, resulting in an increase of less than one percent. On the other hand, the use of reboilers in the beer still and rectifier rather than live steam injection results in a 20 percent decrease in wastewater generation for this system.

As in conventional distillation, the current distillation train is a source of small amounts of volatile organic compounds which are emitted from the vents on column condensers.

2.3.4 DEHYDRATION

When a mixture of ethanol and water is distilled at atmospheric pressure, a minimum boiling point azeotrope is formed. It is at this point (approximately 96 percent ethanol concentration) that further separation of ethanol and water is impossible using simple distillation techniques. To produce anhydrous ethanol (pure ethanol), a third compound (dehydration agent) can be added to the mixture to alter the azeotrope and subsequently permit the removal of all the water from the system. This sequence of events is referred to as dehydration.

Currently, there are two methods for dehydration in the ethanol-for-fuel industry: one method consists of a self-contained add-on unit and is used in beverage alcohol plants that have been converted to produce anhydrous ethanol; the other is designed as an integral part of the distillation system and is used in ethanol-for-fuel facilities. A variety of dehydration agents are available which are suitable for either system, including benzene, hexane, ethyl ether, and gasoline.

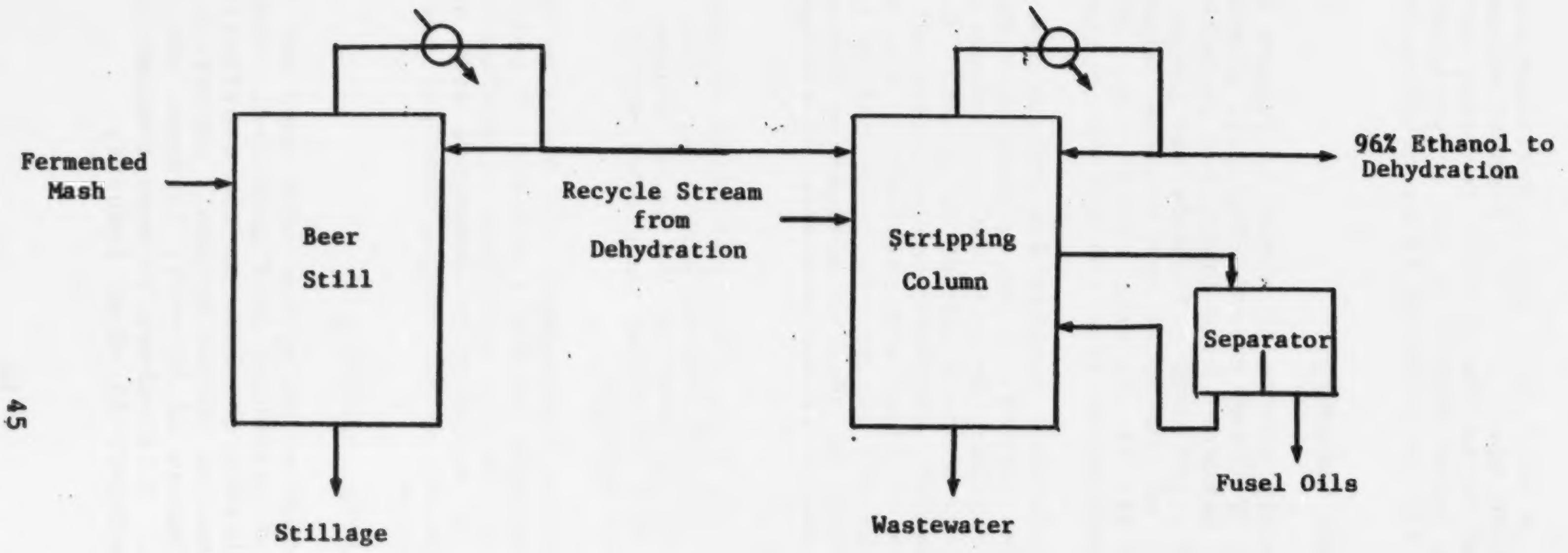
Fermented Mash
Beer Still
Stillage
Recycle Stream from Dehydration
Stripping Column
Wastewater
96% Ethanol to Dehydration
Separator
Fusel Oils

Figure 2-6

CURRENT DISTILLATION DESIGNS

The first system that is discussed uses a distillation column to strip out the dehydration agent from the product ethanol stream; this method is referred to as the solvent recovery method. The second system allows a large amount of the dehydration agent to remain in the ethanol and is referred to as dehydration without solvent recovery.

Dehydration With Solvent Recovery

A typical solvent recovery scheme is shown in Figure 2-7. The solvent currently used by three ethanol-for-fuel plants is benzene. The addition of benzene, both fresh and recycled from the benzene recovery column, produces a ternary azeotrope. In the dehydration column, all of the water and benzene (along with some ethanol) is taken off in the overhead stream. Ethanol, present in excess, is withdrawn from the bottom of the column.

The overheads from the benzene dehydration column are cooled in a separator and form two layers: a water/ethanol-rich bottom layer containing some residual benzene and a benzene/ethanol-rich top layer containing a small amount of water. The bottom layer is sent to the benzene recovery column where all the benzene and ethanol are stripped and recycled to the dehydration column. The stream from the benzene recovery column bottom, which is nearly all water, is sent to wastewater treatment. The top layer from the separator is recirculated to the benzene dehydration column.

The only wastewater stream from the dehydration system is the bottom stream from the benzene recovery system. This stream is very small (less than one percent of the total volume of process wastewater), is low in BOD and total suspended solids, and may contain trace amounts of benzene.

As with distillation column condensers, the vents on dehydration column condensers are sources of small amounts of volatile organics. Also, the vent on the two-phase separator is a source of volatile organics. In addition to compounds such as ethanol and fusel oils, dehydration agents (e.g., benzene) are also emitted from these sources.

Dehydration Without Solvent Recovery

A flow diagram for a dehydration system that does not recover the dehydration agent is presented in Figure 2-8. One ethanol-for-fuel plant uses unleaded gasoline as the dehydration agent and, by leaving the gasoline in the ethanol, satisfies the requirements set by the Bureau of Alcohol, Tobacco, and Firearms (ATF) for denaturation. This scheme is more indicative of future trends for the ethanol-for-fuel industry.

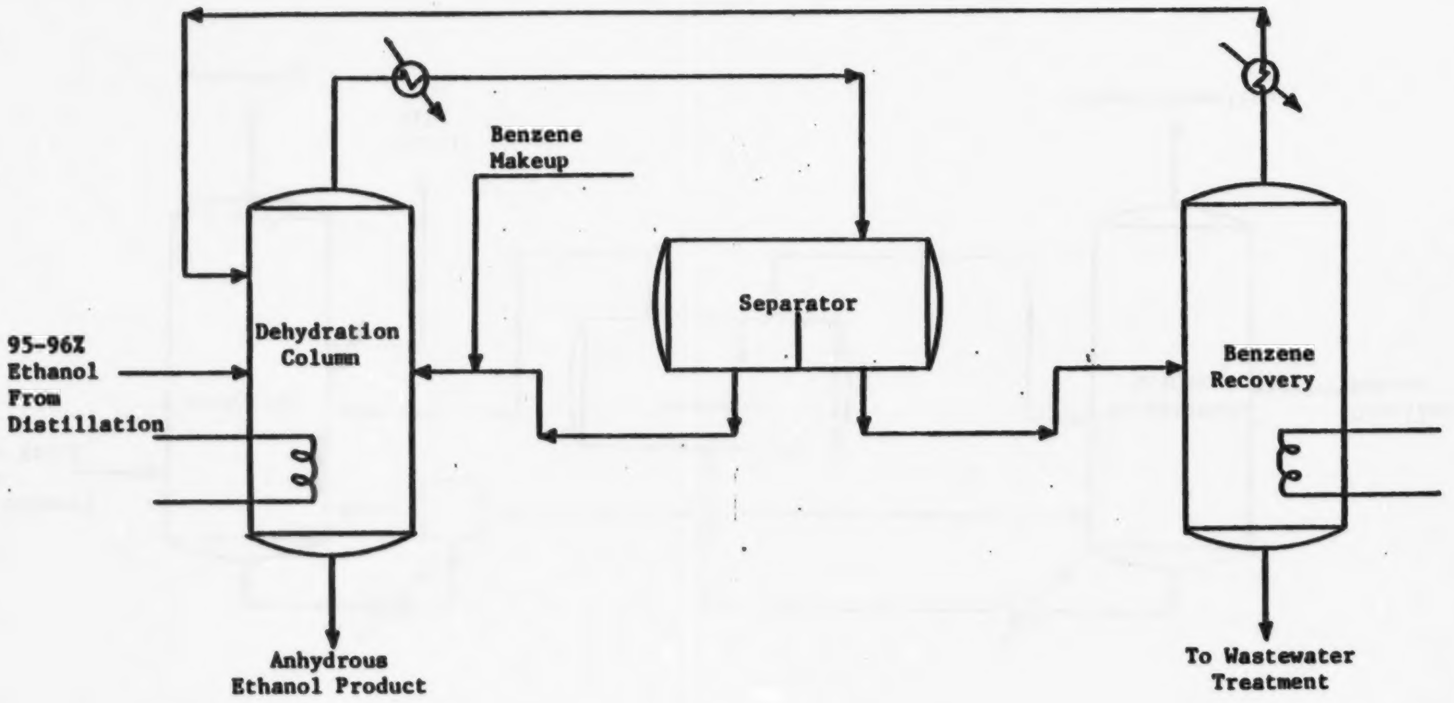
95-96%
Ethanol
From
Distillation
Dehydration
Column
Anhydrous
Ethanol Product
Benzene
Makeup
Separator
Benzene
Recovery
To Wastewater
Treatment

Figure 2-7
DEHYDRATION WITH SOLVENT RECOVERY

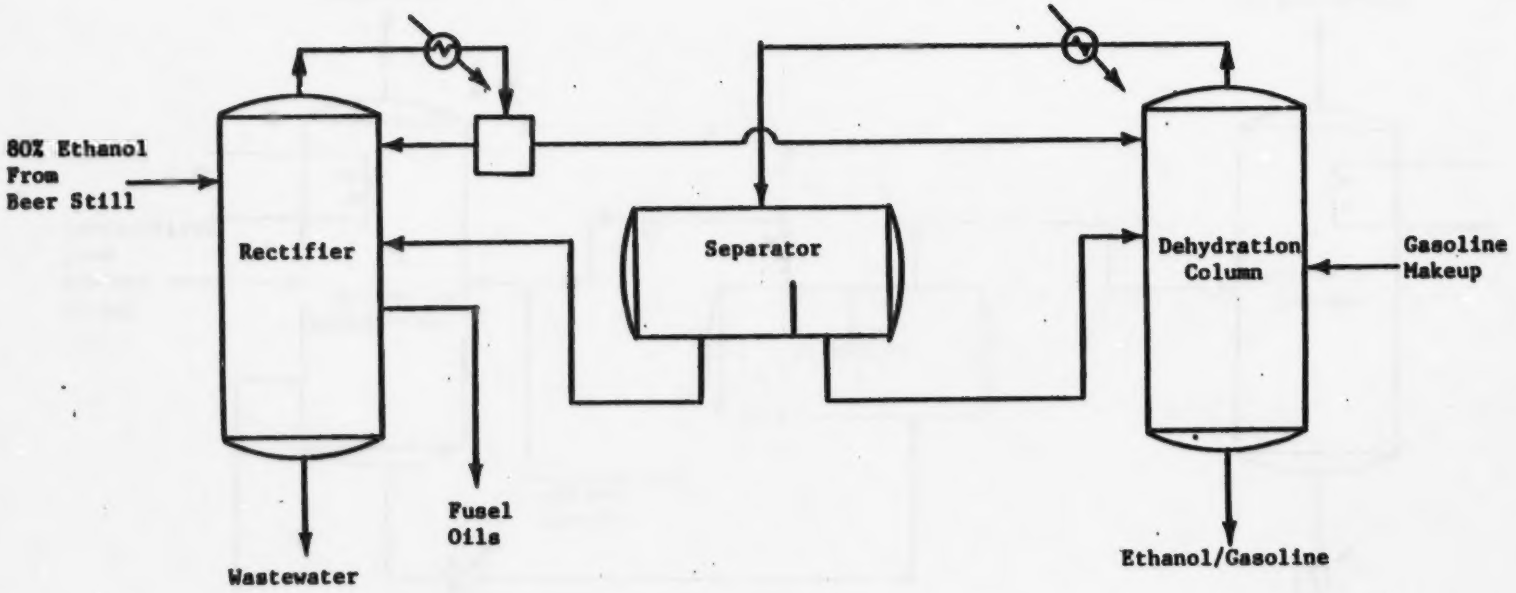
80% Ethanol
From
Beer Still
Rectifier
Separator
Dehydration
Column
Gasoline
Makeup
Fusel
Oils
Wastewater
Ethanol/Gasoline

Figure 2-8
DEHYDRATION WITHOUT SOLVENT RECOVERY

As in the method which uses solvent recovery, the dehydration agent is added to the dehydration column. Operating conditions in this column are only severe enough to remove all of the water (along with some gasoline and ethanol); a 50/50 blend of ethanol and gasoline is withdrawn off the bottom of the column.

This system also sends the overhead stream from the dehydration system to a separator which returns the upper gasoline-rich phase to the dehydration column and the lower ethanol/water layer to the rectifier used in distillation. Thus, water leaves this dehydration system via the rectifier, and there is no wastewater generated from the dehydration system proper.

Air emissions from this dehydration system are similar to those emitted from dehydration systems with solvent recovery.

2.3.5 BY-PRODUCT PROCESSING

Depending on the feedstock and the preparation technique used, the stillage from the bottom of the beer still may be recovered as a marketable, high-protein by-product. Several variations exist in the method of recovering whole spent stillage. Basically, all ethanol plants fall into two categories: (1) those with no recovery of this material, and (2) those utilizing evaporators and dryers for complete recovery.

In some instances, the quantity of stillage does not warrant the capital expenditure required for by-product recovery. This is particularly true if feedstocks other than grain are used which are deficient in protein content (e.g., sugars, cellulose). It is more economical for these plants to dispose of wet stillage to nearby farmers for cattle feed than to install a recovery system. Those plants that do not recover stillage have a substantially different wasteload since the by-product recovery system is the major contributor to total distillery waste.

Figure 2-9 illustrates a typical process for a by-product recovery system. Whole spent stillage is approximately five to seven percent solids; thus, by-product recovery is essentially a dewatering process. The first step consists of passing the whole stillage over a screen. The coarser solids are retained and sent to a press for further removal of soluble solids. The press cake, if dried separately on driers, becomes "distillers light grain." The thin stillage liquid is normally centrifuged to remove suspended solids, then piped to multiple effect evaporators where it is concentrated to a syrup containing about 25 to 50 percent solids. These evaporated solubles may be thermally dried to produce "distillers dried solubles," or more commonly dried with press cake in rotary driers to produce "distillers dark grains."

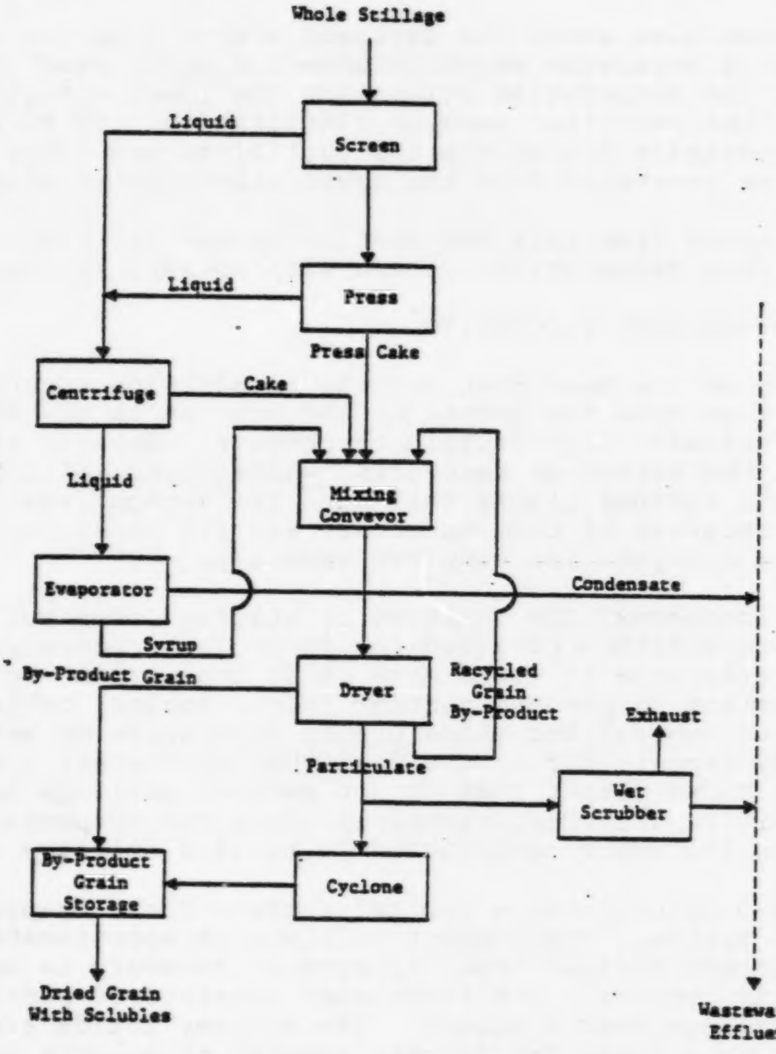
Whole Stillage
Screen
Liquid
Press
Liquid
Press Cake
Centrifuge
Cake
Liquid
Mixing Conveyor
Evaporator
Condensate
Syrup
By-Product Grain
Dryer
Recycled Grain By-Product
Exhaust
Particulate
Wet Scrubber
By-Product Grain Storage
Cyclone
Dried Grain With Solubles
Wastewater Effluent

Figure 2-9

PROCESS FLOW DIAGRAM:
BY-PRODUCT RECOVERY

One ethanol-for-fuel plant uses a cellulose based feedstock. In this case, the lignin is recovered and concentrated as it too is a valuable by-product. Evaporation lowers the moisture content to approximately 50 percent before the lignin solution is pumped to its own processing plant.

The high yeast concentration required in continuous fermentation and the necessary separation of the yeast from the lignin/ ethanol solution before entering the beer still produces a second by-product stream, dried yeast. After the last fermentation vessel in the continuous fermentation train, centrifuges are used to remove the yeast. A portion of the yeast is recycled to the first reactor and the rest is pasteurized to kill the yeast which can then be disposed of or sold as a by-product.

The major contribution to the ethanol-for-fuel plant wasteload is from the by-product recovery system. It can account for as much as 80 percent of the total plant waste. The most significant source of wastewater within the feed recovery system is the condensate from evaporators. Although most plants discard their condensate, at least one grassroots plant recycles up to 95 percent of the condensate to the mashing tank. This practice is indicative of the new plants that will be coming on-line. Finally, dust emanating from grain dryers may constitute another source of wastewater if wet scrubbers are used. Many plants eliminate this water through the use of cyclones and combine the collected dust with by-product grains.

SECTION 3

WASTE STREAM CHARACTERIZATION

3.1 DATA COLLECTION

An extensive literature search revealed that a limited amount of information existed in the literature regarding water use and wastewater quality for ethanol-for-fuel facilities. Consequently, the Agency devised an extensive sampling program to characterize the effluent streams from all ethanol-for-fuel plants and several beverage alcohol plants. This program supplemented the data provided by two other studies: an environmental characterization of an ethanol-for-fuel facility sponsored by the Industrial Environmental Research Laboratory in Cincinnati, Ohio (IERL-Ci), and a sampling program conducted by the Region IV EPA Surveillance and Analysis Division (6) concerning effluents from three rum distilleries.

In addition to these sampling programs, multimedia industry questionnaires were prepared and submitted under authority of Section 308 of the Clean Water Act, Sections 111 and 114 of the Clean Air Act, and Section 3007 of the Resource Conservation and Recovery Act of 1976. Also, National Pollutant Discharge Elimination System (NPDES) permit applications for ethanol plants were reviewed, and EPA regional offices were contacted for pertinent effluent data. The information gathered from these data collection activities and sampling programs are summarized in Table 3-1. This table also specifies whether the data were used in the pollutant parameter treatability assessment.

3.1.1 MULTIMEDIA INDUSTRY QUESTIONNAIRE

A multimedia questionnaire was prepared and submitted to ethanol-for-fuel and beverage alcohol facilities. This questionnaire solicited information concerning water use; generation and control technology for wastewater, air emissions and solid wastes; process configuration; internal stream routing; and chemical application rates. Initially, the questionnaires were sent to the eight ethanol plants scheduled for sampling and analysis. Responses were obtained from plants A01, A03, A06, A07, A10, E02, and E08. A preliminary analysis of these responses demonstrated a lack of data on the efficiency of the control and treatment systems employed. Therefore, the questionnaires were revised to obtain daily monitoring data on untreated and treated waste streams and sent to six beverage alcohol plants. Responses were obtained from plants E04, E05, E12, E13, E17, and E18.

Table 3-1

ETHANOL-FOR-FUEL DATA BASE SUMMARY

Plant Code	Type of Analytical Data	Pollutant Parameter Treatability
A01	3 days, untreated effluent (C, N, P)	No
A02	No data available	No
A03	2 years, untreated and treated effluent (C, N, P)	Yes
A04	No data available	No
A05	No data available	No
A06	3 days, untreated effluent (C, N, P)	No
A07	3 days, untreated and treated effluent (C, N, P)	No
A08	No data available	No
A10	3 days, untreated effluent (C, N, P)	No
E01	5 days, untreated effluent (C, N, P)	No
E02	3 days, untreated and treated effluent (C, N, P)	Yes
E03	5 days, untreated effluent (C, N, P)	No
E04	Average diluted untreated effluent (C)	No
E05	1 year, treated effluent, avg. untreated effluent (C)	Yes
E06	1 day, untreated and treated effluent; treatability data	Yes
E07	1 year, monthly average (C)	Yes
E08	6 days, untreated and treated effluent (C, N, P)	Yes
E09	3 days, untreated effluent (C, N, P)	No
E11	1 year, average untreated and treated effluent (C)	Yes
E12	1 year, average untreated and treated effluent (C)	Yes
E13	1 year, treated effluent and treatability data (C)	Yes
E14	1 year, diluted treated effluent (C)	No
E15	6 months, untreated and treated effluent (C)	Yes
E16	1 year, diluted effluent only (C)	No
E17	1 year, untreated and treated effluent (C)	Yes
E18	2 months, untreated and treated effluent (C)	Yes
E19	1 year, average untreated and treated effluent (C)	No
E20	5 days, untreated effluent (C, N, P)	No

C = Conventional Pollutant Data
N = Nonconventional Pollutant Data
P = Priority Pollutant Data

3.1.2 NPDES PERMIT DATA

After the results from the sampling programs and questionnaire responses were received, EPA regional offices were contacted to obtain NPDES permit information on ethanol plants regarding wastewater treatment systems and effluent monitoring data. Information received from 14 direct dischargers including plants A03, E02, E05, E06, E07, E08, E11, E12, E13, E15, E16, E17, E18, and E19.

3.1.3 EPA REGION IV SURVEILLANCE AND ANALYSIS DIVISION (SAD) PROGRAM

In 1978, the EPA initiated a study aimed at assessing the options for disposal of rum distillery wastes and associated environmental consequences. Region IV EPA/SAD conducted sampling and analyses at plants E01, E03, and E20 for five consecutive days. Composite samples were taken of the undiluted beer still slops or mosto stream and of the combined untreated effluent, where possible. Single grab samples were collected from each facility's raw process water, fermentation tank, aldehyde column, and rectifying column; flow rates of the waste streams were also determined (6,7).

A statistical and engineering analysis demonstrated that the effluent quality of the rum distilleries varied significantly from the effluent of other beverage alcohol plants (as well as from ethanol-for-fuel facilities). Furthermore, the industry profile reveals that there are no rum distilleries providing or planning to provide ethanol-for-fuel. Thus, the effluent data from the rum industry were not presented in this evaluation, however, the data have been included in Appendix E.

3.1.4 IERL-Ci SOURCE TEST EVALUATION

In anticipation of the rapidly developing ethanol-for-fuel industry and subsequent environmental impact, in 1978 the IERL-Ci sponsored a test program as part of its efforts to determine sampling and analytical requirements for ethanol facilities. This program included the monitoring of air emissions and sampling of solid wastes and wastewater effluents. Information concerning the streams tested, sampling frequency, and analytical parameters examined can be found in the EPA report entitled, "Source Test and Evaluation Report: Alcohol Facility for Gasohol Production" (8).

3.1.5 EPA MULTIMEDIA SAMPLING PROGRAM

In 1980, the Effluent Guidelines Division (EGD), the Office of Solid Waste (OSW), and the Office of Air Quality Planning and Standards (OAQPS) of the EPA sponsored a program to characterize effluents, solid wastes, and air emissions from ethanol-for-fuel and beverage alcohol facilities. This multimedia program was undertaken to provide the Agency with a basis for evaluating regulatory aspects of wastewater, solid wastes, and air emissions from the ethanol-for-fuel industry.

Facility Selection

At the inception of the EPA multimedia sampling program, there were only five ethanol plants producing ethanol-for-fuel; all of these plants were selected for sampling. Data were also sought from the beverage alcohol industry which was hypothesized to be analogous to the ethanol-for-fuel industry in terms of the quality and volume of wastewater generated. Three plants (E02, E08, and E09) were chosen from the beverage alcohol industry for sampling and analysis. Statistical data evaluation showed the effluent from beverage alcohol plants to be similar to effluent from ethanol-for-fuel plants and justified the combination of the effluent data from all ethanol facilities tested.

According to the industry profile, approximately 95 percent of the ethanol-for-fuel plants constructed in the next five to ten years were projected to use grain feedstocks. Therefore, plants E08 and E09 (typical grain distilleries) were selected for testing. Plant E08 treats its wastewater using aerated lagoons, rotating biological contactors, and stabilization ponds while plant E09 discharges its wastewaters to a municipal treatment system.

Plant E02, which uses the second most common type of feedstock (sugar cane and citrus molasses), was selected for comparison to grain feedstock beverage alcohol plants and the rum facilities. This facility produces products which range from 50 to 95 percent ethanol. Its wastewater treatment system includes aeration tanks, a clarifier, a polishing pond, and a sludge digester.

Wastewater Sampling

The combined raw wastewaters, treated effluent streams, and several component raw wastewater sources were tested for conventional and priority pollutants, as well as selected nonconventional pollutant parameters and those pollutants listed in Appendix C of the 1976 Consent Decree (Appendix C compounds). All parameters selected for analysis are listed in Tables 3-2 through 3-4. The ethanol facilities, selected streams, and analytical parameters evaluated in this program are summarized in Table 3-5.

The primary EPA reference for sampling effluent streams is in "Sampling and Analysis Procedures for Screening of Industrial Effluents for Priority Pollutants," April 1979 (9). Additional information is found in the June 14, 1979 and December 3, 1979 issues of the Federal Register (10,11). The sampling procedures

Table 3-2

LIST OF 129 PRIORITY POLLUTANTS

Compound Name

1. acenaphthene
2. acrolein
3. acrylonitrile
4. benzene
5. benzidene
6. carbon tetrachloride (tetrachloromethane)

Chlorinated benzenes (other than dichlorobenzenes)

7. chlorobenzene
8. 1,2,4-trichlorobenzene
9. hexachlorobenzene

Chlorinated ethanes(including 1,2-dichloroethane, 1,1,1-trichloroethane and hexachloroethane)

10. 1,2-dichloroethane
11. 1,1,1-trichlorethane
12. hexachlorethane
13. 1,1-dichloroethane
14. 1,1,2-trichloroethane
15. 1,1,2,2-tetrachloroethane
16. chloroethane

Chloroalkyl ethers (chloromethyl, chloroethyl and mixed ethers)

17. bis (chloromethyl) ether*
18. bis (2-chloroethyly) ether
19. 2-chloroethyl vinyl ether (mixed)

Chlorinated naphthalene

20. 2-chloronaphthalene

Chlorinated phenols (other than those listed elsewhere; includes trichlorophenols and chlorinated cresols)

21. 2,4,6-trichlorophenol
22. parachlorometa cresol
23. chloroform (trichloromethane)
24. 2-chlorophenol

Table 3-2 (Continued)

LIST OF 129 PRIORITY POLLUTANTS

Dichlorobenzenes

25. 1,2-dichlorobenzene
26. 1,3-dichlorobenzene
27. 1,4-dichlorobenzene

Dichlorobenzidine

28. 3,3'-dichlorobenzidine

Dichloroethylenes (1,1-dichloroethylene and 1,2-dichloroethylene)

29. 1,1-dichloroethylene
30. 1,2-trans-dischloroethylene
31. 2,4-dichlorophenol

Dichloropropane and dichloropropene

32. 1,2-dichloropropane
33. 1,2-dichloropropylene (1,3-dichloropropene)
34. 2,4-dimenthylphenol

Dinitrotoluene

35. 2,4-dinitrotoluene
36. 2,6,-dinitrotoluene
37. 1,2-diphenylhydrazine
38. ethylbenzene
39. fluoranthene

Haloethers (other than those listed elsewhere)

40. 4-chlorophenyl phenyl ether
41. 4-bromophnyl phenyl ether
42. bis(2-chloroisopropyl) ether
43. bis(2-chloroethoxy) methane

Halomethanes (other than those listed elsewhere)

44. methylene chloride (dichloromethane)
45. methyl chloride (chloromethane)
46. methyl bromide (bromomethane)
47. bromoform (tribromomethane)
48. dichlorobromomethane

Table 3-2 (Continued)

LIST OF 129 PRIORITY POLLUTANTS

49. trichlorofluoromethane*
50. dichlorodifluoromethane*
51. chlorodibromomethane
52. hexachlorobutadiene
53. hexachlorocyclopentadiene
54. isophorone
55. naphthalene
56. nitrobenzene

Nitrophenols (including 2,4-dinitrophenol and dinitrocesol)

57. 2-nitrophenol
58. 4-nitrophenol
59. 2,4-dinitrophenol
60. 4,6-dinitro-o-cresol

Nitrosamines

61. N-nitrosodimethylamine
62. N-nitrosodiphenylamine
63. N-nitrosodi-n-propylamine
64. pentachlorophenol
65. phenol

Phthalate esters

66. bis(2-ethylhexyl) phthalate
67. butyl benzyl phthalate
68. di-n-butyl phthalate
69. di-n-octyl phthalate
70. diethyl phthalate
71. dimethyl phthalate

Polynuclear aromatic hydrocarbons

72. benzo (a)anthracene (1,2-benzanthracene)
73. benzo (a)pyrene (3,4-benzopyrene)
74. 3,4-benzofluoranthene
75. benzo(k)fluoranthane (11,12-benzofluoranthene)
76. chrysene
77. acenaphthylene
78. anthracene
79. benzo(ghi)perylene (1,12-benzoperylene)
80. fluorene
81. phenathrene

Table 3-2 (Continued)

LIST OF 129 PRIORITY POLLUTANTS

82. dibenzo (a,h)anthracene (1,2,5,6-dibenzanthracene)
83. indeno (1,2,3-cd) pyrene (2,3,-o-phenylenepyrene)
84. pyrene
85. tetrachloroethylene
86. toluene
87. trichloroethylene
88. vinyl chloride (chloroethylene)

Pesticides and Metabolites

89. aldrin
90. dieldrin
91. chlordane (technical mixture and metabolites)

DDT and metabolites

92. 4,4'-DDT
93. 4,4'-DDE(p,p'DDX)
94. 4,4'-DDD(p,p'TDE)

endosulfan and metabolites

95. a-endosulfan-Alpha
96. b-endosulfan-Beta
97. endosulfan sulfate

endrin and metabolites

98. endrin
99. endrin aldehyde

heptachlor and metabolites

100. heptachlor
101. heptachlor epoxide

hexachlorocyclohexane (all isomers)

102. a-BHC-Alpha
103. b-BHC-Beta
104. r-BHC (lindane)-Gamma
105. g-BHC-Delta

Table 3-2 (Continued)

LIST OF 129 PRIORITY POLLUTANTS

polychlorinated biphenyls (PCB's)

106. PCB-1242 (Arochlor 1242)
107. PCB-1254 (Arochlor 1254)
108. PCB-1221 (Arochlor 1221)
109. PCB-1232 (Arochlor 1232)
110. PCB-1248 (Arochlor 1248)
111. PCB-1260 (Arochlor 1260)
112. PCB-1016 (Arochlor 1016)

Metals and Cyanide, and Asbestos

114. Antimony (Total)
115. Arsenic (Total)
116. Asbestos (Fibrous)
117. Beryllium (Total)
118. Cadmium (Total)
119. Chromium (Total)
120. Copper (Total)
121. Cyanide (Total)
122. Lead (Total)
123. Mercury (Total)
124. Nickel (Total)
125. Selenium (Total)
126. Silver (Total)
127. Thallium (Total)
128. Zinc (Total)

Other

113. Toxaphene
129. 2,3,7,8-tetra chlorodibenzo-p-dioxin (TCDD)

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*Bis (chloromethyl) ether was deleted from this list on February 4, 1984 (46 FR 10723); trichlorofluoromethane and dichlorodifluoromethane were deleted on January 8, 1981 (46 FR 2266). However, testing for the ethanol-for-fuels industry was performed prior to these deletions, so for the purposes of this document, the list appears with all the original 129 priority pollutants.

Table 3-3

CONVENTIONAL POLLUTANTS

Biochemical Oxygen Demand (BOD_5)

pH

Oil and Grease

Total Suspended Solids (TSS)

Fecal Coliform

Table 3-4

NONCONVENTIONAL POLLUTANTS ANALYZED

Acidity
Alkalinity
Ammonia
Chemical Oxygen Demand (COD)
Dissolved Oxygen (DO)
Settleable Solids (SS)
Temperature
Total Kjeldahl Nitrogen
Total Organic Carbon (TOC)
Total Phenol (4AAP)
Total Phosphorus
Total Solids (TS)
Total Dissolved Solids (TDS)
Total Volatile Solids (TVS)
Aluminum
Barium
Bismuth
Boron
Calcium
Cobalt
Gold
Iron
Lithium
Magnesium
Manganese
Molybdenum
Palladium
Platinum
Sodium
Telurium
Tin
Titanium
Vanadium
Yttrium

Table 3-4 (Continued)

NONCONVENTIONAL POLLUTANTS[1] ANALYZED

Acetone
n-Alkanes
Biphenyl
Chlorine
Dimethyl ether
Diethyl ether
Dibenzofuran
Diphenyl ether
Methyl ethyl ketone
Nitrites
Styrene
Dimethyl amine
Diethyl amine
Dibutyl amine
Diphenyl amine
Camphor
Cumene
-Terpineol

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[1] Compounds presented in Appendix C of 1976 Consent Decree.

Table 3-5

EGD/EPA SAMPLING PROGRAM

Plant Code	Stream Sampled	Conventionals and Nonconventionals	Priority Pollutants	Appendix C[1] Compounds	Asbestos	Sample Type	Number of Days Sampled
A01	Source Water	X	X			Grab	1
	Stripping Column Bottoms	X	X			24-Hr Composite	1
	Total Plant Effluent	X	X			24-Hr Composite	3
A03	Treated Effluent		X	X		Grab	2
	Source Water		X	X		Grab	2
A06	Source Water	X	X	X		Grab	3
	Wash Water	X	X			Grab	3
	Evap. Condensate[2]	X	X			Grab	2
	Stripping Column Bottoms	X	X	X	X	Grab	3
A07	Source Water	X	X			Grab	3
	Total Raw Waste	X	X	X	X	24-Hr Composite[3]	3
	Evap. Condensate	X	X			24-Hr Composite	3
	Influent to WW Treatment	X	X			24-Hr Composite[3]	3
	Treated Effluent	X	X			24-Hr Composite	3
A10[6]	Source Water	X	X			Grab	2
	Whey Truck Wash[7]	X	X			Grab	1
	Yeast Truck Wash	X	X			Grab	3
	Evap. Condensate	X	X			24-Hr Composite	2
	Sewer No. 1	X	X			24-Hr Composite	2
	Sewer No. 2	X	X			24-Hr Composite	
	Aeration Pond Effluent	X	X	X	X	24-Hr Composite	2
E02	Source Water	X	X			Grab	3
	Evap. Condensate[5]	X	X			Grab	2
	Noncontact Cooling Water	X	X			Grab	3
	Total Raw Waste	X	X			24-Hr Composite	3
	Treated Effluent	X	X			24-Hr Composite	3
	Diluted Treated Effluent	X	X	X	X	24-Hr Composite	3
E08	Source Water	X	X			Grab	6
	#1 Aerated Lagoon Effluent	X	X			24-Hr Composite	6
	RBC Effluent	X	X			24-Hr Composite	6
	#2 Aerated Lagoon Effluent	X	X			24-Hr Composite	6
	Influent to Air Flotation Unit	X	X			24-Hr Composite	6
	Air Flotation Effluent	X	X			24-Hr Composite	6

Table 3-5 (Continued)

EGD/EPA SAMPLING PROGRAM

Plant Code	Stream Sampled	Conventionals and Nonconventionals	Priority Pollutants	Appendix C[1] Compounds	Asbestos	Sample Type	Number of Days Sampled
E09	Source Water River	X	X			Grab	3
	Source Water Well	X	X			Grab	3
	Flash Cooler Condensate	X	X			24-Hr Composite[4]	2
	Mixing Basin Effluent	X	X			24-Hr Composite	3
	Total Raw Waste	X	X	X	X	24-Hr Composite	3

---

[1] Pollutants listed in Appendix C of 1976 Consent Decree.
[2] Day 1 sample was lost.
[3] A 12-hour composite was collected for day 1 only.
[4] No sample collected on day 1; a 12-hour composite was taken on day 2.
[5] Evaporators were not running on day 1.
[6] No samples taken on day 2 due to equipment problems at plant.
[7] Whey truck not present day 1 and day 2.

described briefly below and detailed in Appendix C are based on these three references.

Each effluent water sample consists of a number of blank, grab, and composite subsamples. Depending on which parameters are determined at each site and on the effluent stream composition, some of these subsamples were not collected. Additional parameters such as pH, temperature, and dissolved oxygen were to be performed on-site.

For composite samples, compositing time is typically in the range of 24 hours, with a constant minimum aliquot of 100 ml taken at intervals of 15 to 30 minutes to give a minimum composite volume of 5 liters. Samples were to be composited automatically, utilizing ISCO Model 1580 Automatic Samplers.

Some of the parameters listed in Table 3-5 were collected as grab samples. Grab samples were obtained at the midpoint of the compositing period in a turbulent, well-mixed section of the effluent stream. Grab sampling was conducted because of potential rapid change in the parameter of interest (volatile organics, phenolics, cyanides, etc.) or because of potential contamination from the sampling operation (asbestos, fecal coliform).

The methodology of stream selection for wastewater sampling included collecting a 24-hour composite on three consecutive days for the total raw waste stream from the ethanol plant and any major sources of wastewater that were accessible. Also, three 24-hour composite samples were collected of the effluent streams from wastewater treatment systems to obtain information regarding treatment system efficiency. Finally, raw makeup water samples were collected to determine net discharge concentrations. The characteristics of the makeup water did not change over a 24-hour period; therefore, daily grab samples were obtained for this stream.

Solid Waste Sampling

For solid waste sampling, all major sources of solid wastes and by-products were collected for analyses. In addition, samples of the feedstocks were collected and tested to determine if the raw materials might be the source of toxic pollutants or contaminants. Various techniques were used to collect the solid samples; a description of the sampling procedures used is provided in Appendix A.

The solid samples, as well as their acetic acid and distilled water leachates were analyzed for pesticides, metals, and selected nonconventionals according to procedures outlined in RCRA. The parameters tested and analytical methods used are outlined in Appendix B. The analytical results of the solid waste testing are presented in Appendix D. A detailed discussion of the solid wastes associated with ethanol production is provided in Section 3.7.

Gas Phase Sampling

Whenever possible, the methods used to characterize the air emissions from the ethanol plants were EPA-referenced methods. These referenced methods are located in the Federal Register, Vol. 42, No. 160, August 18, 1977 (12). In situations where an EPA-referenced method does not exist for a particular parameter, a proposed method was used. A detailed description of the sampling procedures used at each site is given in Appendix A.

All major point sources of air emissions that were accessible within the plant were examined for flow rates and concentrations of suspected air pollutants. The accessibility of a source was determined by its location and size, and the logistics of erecting scaffolding, if necessary. Fugitive emissions (unintentional discharges or leaks of volatile organic compounds from process valves, process drains, open-ended lines, and flanges) were also sampled at two facilities. The results of the air emissions testing are presented in Appendix D. A detailed discussion of the air emissions associated with ethanol production is provided in Section 3.6.

Sample Point Selection

A presampling visit was made to each candidate ethanol facility to assess the operation of the plant and the accessibility of the air emission point sources and wastewater streams. The final selection of the sample points and sample type based on the site visits are summarized in Table 3-5 and discussed below.

Plant A01. During the site visit, it was discovered that many major sources of wastewater were inaccessible. The only streams that were possible to test included the bottom stream from the benzene recovery column, the makeup water, and the total ethanol plant effluent stream. The wastewater treatment system pretreats all plant A01 wastewaters before discharge to the municipal wastewater treatment plant. The effluent stream from this treatment system was not tested as the ethanol plant wastewaters comprise only a small fraction of the total load to the treatment plant.

The vents for air emissions were located approximately 20 meters from the ground and extended from the side of the ethanol plant building. As such, the vents were inaccessible and no air sampling was proposed.

This ethanol plant routes all solid wastes associated with ethanol production to a centralized feed house where wastes from other processes are handled. The solid waste from the ethanol facility could not be sampled separately; thus, no solid waste sampling was proposed for this facility.

Plant A03. This plant was sampled for air, water, and solid wastes in a 1979 program sponsored by IERL-Ci (8). As a result, only two streams were selected for additional testing for Appendix C compounds and priority pollutants. For this study, grab samples of the secondary biological treatment system effluent and the source water were taken on two successive days. The IERL-Ci study did not analyze solid wastes for metals; therefore, samples were collected from the feedstock grain, by-product grains, and biosludge streams for metal analyses.

Plant A06. This facility does not combine its waste streams or treat its wastewater; therefore, only the major waste streams (benzene stripping column bottoms, evaporator condensate, and wash waters) were sampled. During the test effort, it was determined that plant A06 was operating under start-up conditions. Due to the unstable conditions of start-up operations, grab samples were collected rather than composite samples.

The sources of air emissions that were selected include the vents from fermenters, product storage, and the steam ejector used for the vacuum system. Also, the outlet from the cyclone used to control particulate emissions from the by-product grains dryer and a CO_2 degasser vent were chosen. These sources were hypothesized to be the major sites for particulate, inorganic, and hydrocarbon emissions.

No solid wastes were sampled from this facility.

Plant A07. In addition to the total raw waste stream from plant A07, the evaporator condensate stream was selected since it constitutes a major portion of the total raw waste. As in all other plants, the makeup or source water stream was sampled to determine net values for pollutant concentrations.

Several wood pulping processes occur at plant A07 and the wastes from these processes are combined with the effluent from the ethanol plant. The ethanol plant contributes 40 to 65 percent of the BOD_5 load and 10 percent of the total wastewater volume. Due to the high percentage BOD_5 contribution from the ethanol plant, the total plant raw wastewater and treated effluent from plant A07's wastewater treatment system were selected for sampling.

No air sampling was attempted at this facility due to the inaccessibility of sample points for air emissions. Also, the solid wastes are routed to a lignin plant and were not selected for sampling.

Plant E08. The wastewater sampling at this facility was confined to the wastewater treatment system so that treatment system efficiency data could be gathered. In addition to the total untreated and treated effluent, samples were collected for six days from the first aeration basin effluent, the rotating biological contactors (RBC) effluent, and the influent to the air flotation unit. A treatability study using a granular media filter was also conducted for five days each on the first aeration basin effluent and the RBC effluent (13).

The grain dust generated by the milling operation is collected by a cyclone and baghouse in series. The duct from the baghouse to the atmosphere was chosen for sampling. The by-product centrifuges decrease the water content of the distillers dried grains (DDG). Vents from the centrifuges were easily accessible on the dryer house roof and therefore were included for sampling. Also accessible on the dryer house roof was the main dryer stack; this stack was the primary point source that was sampled. The vents on the cooker/cooler tanks, distillation system (beer still and reboiler) and, ethanol storage tanks were all inaccessible for sampling.

Both inlet grain and the DDG's were sampled from bulk storage piles. Since the wastewater treatment system wastes no sludge, the two streams mentioned above were the only solid streams sampled.

Plant E09. This plant combines all of its wastewater, except sanitary wastes and flash cooler condensate, into a receiving tank called the distillery waste basin. This distillery basin, which is discharged to the local municipal treatment plant, was selected for sampling. The mixing basin, which receives all acidic and alkaline wastes for neutralization prior to being routed to the distillery waste basin, was also identified for sampling. Finally, the flash cooler condensate, which is discharged directly to the river, was selected for sampling.

The condenser vents were located 30 meters from the ground and were inaccessible. The dryer house stack was rectangular and located on top of a roof which could not support scaffolding; thus it was not chosen for sampling.

There are two solid waste streams from this plant: feedstock grain and by-product grains. Both of these streams were chosen for sampling and analysis.

Plant E02. In addition to total raw waste and treated effluent, the evaporator condensate stream (which is the major contributor to plant waste load) was chosen for sampling at this facility. Also, since the treated effluent stream is diluted with noncontact cooling water before being discharged to a local stream, the cooling water stream and diluted effluent were selected for sampling. Both the noncontact cooling water and makeup water were to be sampled as grabs since the quality of these streams was not expected to change over a 24-hour period.

Air emission sources at plant E02 were inaccessible for sampling. The types of solid samples that were proposed for collection at this facility were all three feedstocks used, the by-products produced, and the wasted biosludge from the bottom of the sludge thickener. The feedstock samples included cane molasses, citrus molasses, and the juice obtained from pressing orange peels (pressed orange liquor). The by-product samples included the beer still bottom stillage and the condensed molasses solubles.

Plant A10. Ethanol production at plant A10 is one of many processes conducted at this facility. The wastes from the ethanol plant and other production processes are routed to a common plant sewer system. To properly characterize the ethanol plant, the sewer line upstream and downstream of the ethanol plant was selected for testing. Also, the evaporator condensate stream, which is a major waste stream, was chosen for sampling. To obtain treatment system efficiency information, the effluent from the aeration pond was selected for analysis. Truck washings of cheese whey and brewers' yeast, which are sent to the local municipal treatment plant, were also identified for sampling.

As with many other ethanol facilities, the point sources for air emissions proved to be inaccessible and were not considered in the test effort. Solid waste streams chosen included by-product condensed cheese whey solubles (CWS), core samples of land that had been subjected to spray irrigation with treated effluent, and samples of feedstock cheese whey and brewers' yeast.

3.2 STATISTICAL DATA EVALUATION

The ethanol-for fuel industry is a new industry for which limited data are available concerning effluent quality and treatability. To augment the data base, additional data were obtained from the beverage alcohol industry which was hypothesized from an engineering standpoint to be similar to the ethanol-for-fuel industry in terms of effluent quality and volume of wastewater generated. Thus, there are two objectives in this section. The first is to determine if beverage alcohol plants and ethanol-for-fuel plants differ significantly with respect to the amount or quality of effluent generated. Beverage alcohol facilities which are significantly different from ethanol-for-fuel plants are to be excluded from the data base. The second objective is to determine if there are factors which significantly differentiate groups within the ethanol-for-fuel industry (as represented by the available ethanol-for-fuel plants and the statistically similar beverage alcohol plants).

The results of an engineering and statistical analysis revealed that the three rum facilities were significantly different from the ethanol-for-fuel facilities and the other beverage alcohol plants in terms of effluent quality. The rum facilities were found to have significantly higher concentrations of TSS and BOD_5 because no recovery of by-product grains is practiced (i.e., stillage is incorporated into total plant effluent). The statistical analysis showed no significant differences in effluent quality between the ethanol-for-fuel facilities and the remaining beverage alcohol plants. A detailed description of the statistical methods used is provided in Appendix F.

AVAILABLE DATA

A statistical analysis was conducted using untreated effluent quality data and flow rate data from 13 ethanol facilities (A03, A06, A07, A10, E01, E02, E03, E08, E09, E15, E17, E18, and E20). These are the only facilities for which flow rate data and untreated effluent quality data were available. These data were derived from the following sources:

1. 1978 EPA/IERL study to characterize the waste streams of an alcohol facility.
2. 1980 EPA/EGD screen sampling program for effluent guidelines development.
3. EPA Regional NPDES permit monitoring data.
4. EPA/EGD Industry Questionnaires.
5. 1978 Region IV EPA study of rum distillery wastewaters.

The analytical parameters that were evaluated in the statistical analyses were total suspended solids (TSS) and five-day biochemical oxygen demand (BOD_5). These parameters were selected because, historically, they have been used as indicators of water quality in designing biological treatment systems and in monitoring treatability. Sufficient data were not available on other analytical parameters to use them in the statistical analysis.

The BOD_5 and TSS data available for performing these analyses are summarized in Table 3-6. These data fit a lognormal distribution better than a normal distribution; therefore, natural logarithms of the data were used in the statistical analysis.

Table 3-6

DATA AVAILABLE FOR STATISTICAL ANALYSES

Facility Type	BOD_5 No. of Observations	TSS No. of Observations
Ethanol-For-Fuel		
A03	66	152
A06	3	3
A07	3	3
A10	2	2
Beverage Alcohol		
E01*	5	5
E02	3	3
E03*	5	5
E08	7	7
E09	3	3
E15	5	5
E17	165	25
E18	54	23
E20*	5	5

*Rum producing facilities

In addition to BOD_5 and TSS, total plant flow rate as a function of ethanol production was evaluated in the statistical analysis. Daily observations for plant flow rate and ethanol production were not available for most plants. Therefore, the analysis considered the ratio of average flow rate to average ethanol production for each facility.

The approach that was taken to determine whether these facilities differ with respect to average effluent quality consisted of performing a single classification analysis of variance, with facility as the classification variable. This was followed by a multiple comparison procedure, which was used to classify facilities into groups with similar average effluent quality. These groups of facilities were then examined to determine which of several potential factors may have been responsible for the differences observed between groups.

To use the analysis of variance method, individual observations are needed to account for daily variation within a facility. However, daily observations for plant flow rate are not available for most of the plants examined. Therefore, the approach taken to evaluate flow rate was to classify the flow ratio (ratio of average flow rate to average ethanol production) using the multiple comparison procedure. If different groups result, they would then be examined (as with effluent quality) to determine which factors may have been responsible for the different groups.

GROUPINGS BASED ON EFFLUENT QUALITY AND FLOW RATIO

The analysis of variance tested whether the 13 facilities differ with respect to average effluent quality. This analysis indicated that some of the 13 facilities tested had significantly different average concentrations of TSS and BOD_5.

Duncan's multiple range test was then used to compare the average concentrations of TSS or BOD_5 for each pair of facilities. Duncan's test classified those facilities with significantly different average concentrations of TSS or BOD_5 into separate groups, and those facilities with similar average concentrations into the same group. The procedure used to group facilities takes into account the fact that the average concentrations of TSS or BOD_5 were more precisely estimated at those facilities where more data were available.

Table 3-7 presents the facilities within each group and the average TSS and BOD_5 concentration in the logarithm scale for each facility. Within each group the parameters are listed in descending order for average TSS and BOD_5 concentration. The analyses shows two distinct groups for BOD_5 and TSS. Both

Table 3-7

GROUPING OF FACILITIES BASED ON UNTREATED EFFLUENT QUALITY

TSS		BOD$_5$	
High	Low	High	Low
E01 (16.2)		E20 (17.4)	
E20 (16.1)		E01 (17.3)	
	E02 (13.4)		E03 (14.7)
	E03 (13.1)		A07 (14.3)
	E09 (13.1)		E02 (14.2)
	E15 (12.8)		A06 (14.0)
	A03 (12.8)		E09 (14.0)
	E08 (11.8)		A03 (14.0)
	A10 (11.7)		A10 (13.8)
	E17 (11.7)		E18 (13.6)
	A07 (11.6)		E15 (13.6)
	E18 (11.3)		E17 (13.5)
	A06 (10.0)		E08 (13.1)

Notes: Groups were selected using Duncan's Multiple Range Test. Numbers in parentheses are facility means given in ug/l.

plants in the high groups are rum facilities. Also, the third rum facility (plant E03) has the highest value in the low BOD_5 group and the second highest value in the low TSS group. There is strong evidence from these statistical analyses that the rum facilities differ from both beverage alcohol plants and ethanol-for-fuel plants based on TSS and BOD_5. The rum facilities are not part of the ethanol-for-fuel industry and are not considered to be typical of future plants in the industry that will use sugar feestocks. Therefore, data from the rum facilities are excluded from the data base for the statistical analyses.

Disregarding the rum plants, Table 3-7 shows that the ethanol-for-fuel facilities are interspersed with the beverage alcohol facilities. This distribution indicates these plants cannot be distinguished from one another on the basis of BOD_5 or TSS.

Duncan's multiple range test was also used to compare the flow ratios for each pair of facilities. The results of this test indicate that all of the facilities fall into the same group.

ANALYSIS OF POTENTIAL FACTORS AFFECTING EFFLUENT QUALITY AND FLOW RATIO

Based on the information presented in Sections 2 and 3, the following factors were selected as having the greatest potential to affect effluent quality and volume from an engineering standpoint:

1. Process variations
2. Feedstocks
3. Final products
4. Plant age
5. Plant size

Tables 3-8, 3-9, and 3-10 show the relationship between these factors and the facilities grouped in terms of BOD_5, TSS, and flow ratio.

Process Variations

The five major processing steps associated with ethanol production are feedstock preparation, fermentation, distillation, dehydration, and by-product processing. As the data in Section 3 show, the only steps which might significantly affect effluent quality are variations in feedstock preparation and by-product processing.

Table 3-8

RELATIONSHIP BETWEEN ETHANOL FACILITIES AND EVALUATION FACTORS FOR TSS*

	High Group		Low Group										
Evaluation Factors	E01	E20	E02	E03	E09	E15	A03	E08	A10	E17	A07	E18	A06
Process Variations													
By-Product Recovery (Yes) No Recovery (No)	No	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Feedstock													
Grain-Derived (G) Sugar-Derived (S)	S	S	S	S	G	G	G	G	S	G	S	G	G
Final Product													
<50% Ethanol (Low) >90% Ethanol (High)	Low	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High
Plant Age (Years)													
<15 (New) >15 (Old)	Old	Old	New	Old	Old	Old	Old	Old	New	Old	Old	Old	New
Plant Size (m^3/day Ethanol)													
0-25, small (S) 25-50, medium (M) >50, large (L)	L	M	M	S	L	S	L	M	M	S	L	S	M

*Facilities are listed in order of decreasing TSS concentration.

Table 3-9

RELATIONSHIP BETWEEN ETHANOL FACILITIES AND EVALUATION FACTORS FOR BOD_5*

	High Group		Low Group										
Evaluation Factors	**E20**	**E01**	**E03**	**A07**	**E02**	**A06**	**E09**	**A03**	**A10**	**E18**	**E15**	**E17**	**E08**
Process Variations													
By-Product Recovery (Yes) No Recovery (No)	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Feedstock													
Grain-Derived (G) Sugar-Derived (S)	S	S	S	S	S	G	G	G	S	G	G	G	G
Final Product													
≤50% Ethanol (Low) ≥90% Ethanol (High)	Low	Low	Low	High	High	High	High	High	High	Low	Low	Low	Low
Plant Age (Years)													
<15 (New) >15 (Old)	Old	Old	Old	Old	New	New	Old	Old	New	Old	Old	Old	Old
Plant Size (m^3/day Ethanol)													
0-25, small (S) 25-50, medium (M) >50, large (L)	M	L	S	L	M	M	L	L	M	S	S	S	M

*Facilities are listed in order of decreasing BOD_5 concentration.

Table 3-10

RELATIONSHIP BETWEEN ETHANOL FACILITIES AND EVALUATION FACTORS FOR FLOW RATIO*

Evaluation Factors	E09	E02	E08	A07	E17	E15	A10	E20	E18	E03	E01	A03	A06
Process Variations													
By-Product Recovery (Yes) No Recovery (No)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	No	No	Yes	Yes
Feedstock													
Grain-Derived (G) Sugar-Derived (S)	G	S	G	S	G	G	S	S	G	S	S	G	G
Final Product													
<50% Ethanol (Low) ≥90% Ethanol (High)	High	High	Low	High	Low	Low	High	Low	Low	Low	Low	High	High
Plant Age (Years)													
<15 (New) >15 (Old)	Old	New	Old	Old	Old	Old	New	Old	Old	Old	Old	Old	New
Plant Size (m^3/day Ethanol)													
0-25, small (S) 25-50, medium (M) >50, large (L)	L	M	M	L	S	S	M	M	S	S	L	L	M

*Facilities are listed in order of decreasing flow ratio value.

By-Product Processing

Two methods of by-product processing are in use in the industry:

1. Concentrating and drying stillage to produce by-product animal feed.

2. Concentrating and routing the stillage stream to another processing unit.

The first option is used by all the plants using a corn feedstock (A03, E09, E15, E08, and E17) and the molasses and cheese whey plants (E02 and E10, respectively). Plant A07 uses the second option to process spent sulfite liquor and a by-product lignin stream. There is no evidence to support that the condensate discharged from by-product processing option 1 would be significantly different from option 2 in terms of effluent quality or volume.

The rum plants (E01, E03, and E20), on the other hand, discharge whole stillage (the major source of waste in an ethanol facility) without processing. Although this does not affect the volume of wastewater generated, it accounts for the high TSS and BOD_5 values observed for the rum facilities as indicated in Tables 3-8 and 3-9.

Feedstocks and Feedstock Preparation

Feedstock preparation techniques vary according to the type of feedstock processed. The plants examined had two types of feedstock: those requiring saccharification (grain-derived) and those already containing high concentrations of fermentable sugars (sugar-derived). The detailed preparation techniques for each class of feedstock are outlined in Section 2, Industry Profile.

As Tables 3-8 and 3-9 show, only sugar-derived feedstocks can be found in the group with high TSS and high BOD_5 values. However, plants using sugar-derived feedstocks are also interspersed among the grain distilleries in the low TSS and BOD_5 groups. Also, Table 3-10 does not show that these factors affect flow ratios. Therefore, no data are available to conclude that feedstock type or feedstock preparation techniques significantly affect waste streams from plants in the ethanol-for-fuel industry.

Final Products

Most plants providing ethanol-for-fuel produce the same product: anhydrous ethanol. In cases where the plant is a partially converted beverage alcohol plant, 50 to 95 percent ethanol may also be sold as a product. Any difference in wastewater generation between a 50 percent and a 100 percent product is due to the addition of a rectification column and a dehydration unit. The quantity of wastewater generated from these units would increase the total plant effluent volume by less than 3 percent. Table 3-10 also indicates that the final product produced has no effect on wastewater production. Furthermore, the quality of the water removed in rectification and dehydration is, in many cases, better than the intake water for most pollutant parameters. Thus, in accordance with the information in Tables 3-8 and 3-9, the type of product produced does not affect the quality or quantity of the total plant effluent.

Plant Age

The effective age of a processing operation is usually difficult if not impossible to define because there is often little correlation between the age of a plant and the age of the equipment used within the plant. A processor may constantly replace worn-out equipment with new equipment, or, in some cases, install old equipment in a new building. Tables 3-8 and 3-9 show that plants of different age groups can be found in both high and low groups of BOD_5 and TSS. Also, Table 3-10 shows no relationship between plant age and flow ratio. Therefore, data are not available which would support distinct differences in waste generation and effluent quality within the ethanol-for-fuel industry on the basis of plant age.

Plant Size

In regard to plant size, the ethanol production capacity varied from 17 cubic meters of anhydrous ethanol per day at plant E03 to 230 cubic meters of anhydrous ethanol per day at plant E09. Effluent quality is not a function of plant size as Tables 3-8 and 3-9 show; plants of different size groups can be found interspersed in the high and low TSS and BOD_5 groups. Furthermore, Table 3-10 shows that the wastewater generated to ethanol produced ratio does not vary as a function of plant size.

3.3 WATER USE AND EFFLUENT SOURCE

As Figure 3-1 illustrates, the sources of wastewater from an ethanol plant include flash cooler condensate from cooking and cooling, rectifier bottoms and beer still bottoms from distillation, benzene stripping column bottoms from dehydration, evaporator condensate from by-product processing, equipment wash water, noncontact cooling water, boiler blowdown, and ash sluice water. In most ethanol plants, the noncontact cooling water stream is discharged directly without treatment and seldom combined with ethanol plant wastes, although the noncontact cooling water at plant E02 is combined with the treated effluent to dilute the final discharged effluent. Because the noncontact

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1.0
4.5
5.0
5.6
6.3
7.1
8.0
2.8
3.2
3.6
4.0
2.5
2.2
2.0
1.1
1.8
1.25
1.4
1.6

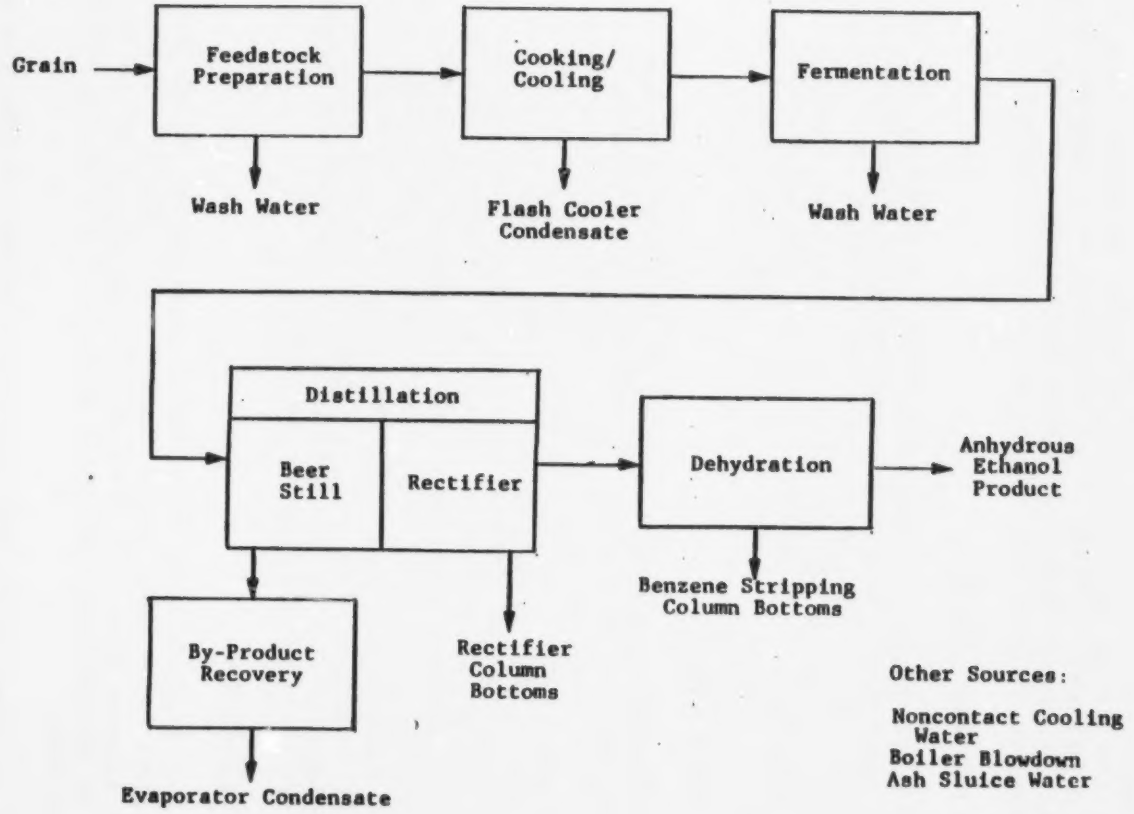
Grain
Feedstock Preparation
Wash Water
Cooking/ Cooling
Flash Cooler Condensate
Fermentation
Wash Water
Distillation
Beer Still
Rectifier
Dehydration
Anhydrous Ethanol Product
By-Product Recovery
Evaporator Condensate
Rectifier Column Bottoms
Benzene Stripping Column Bottoms
Other Sources:
Noncontact Cooling Water
Boiler Blowdown
Ash Sluice Water

Figure 3-1

MAJOR SOURCES OF WASTEWATER FOR ETHANOL FACILITIES cooling water is not treated in the ethanol-for-fuel industry, it is not addressed in this document. Also, boiler blowdown and ash sluice water are not considered as there is no data available from ethanol plants which use coal-fired boilers.

The extent to which each of the remaining wastewater sources contributes to the total plant raw waste varies and is a function of several design and process parameters, including the choice of biomass feedstock, the form and extent of by-product recovery or extraction, the reuse and recycle of water streams, and the product quality desired. Table 3-11 presents the approximate percentages that each of these streams contributes to the total plant wastewater volume for three grain distilleries.

3.3.1 COOKING AND COOLING

Depending on the type of equipment used in cooking and cooling of the mash, a potential source of wastewater is the condensate from flash coolers. A flash cooler is used to cool the cooked mash to a temperature suitable for conversion. This is accomplished by subjecting the mash to a partial vacuum; the subsequent evaporation of liquid causes a loss of heat. The condensate from this evaporated liquid amounts to 0.3 to 1.0 m^3 per 1,000 kg of grain processed (8,14).

Priority pollutant analyses conducted at plant A10 for the flash cooler condensate stream revealed no toxic compounds present in amounts greater than 10 ug/l. BOD_5 values for plants A03, E09, and E14 varied from 13 to 1,900 mg/l, with an average of about 900 mg/l. The BOD_5 concentration of the flash cooler condensate is related to the entrainment of dissolved organic substances in the flashed vapors. This entrainment is a function of the type of equipment used and the efficiency achieved. Total suspended solids were low, with mean values of 5 and 30 mg/l obtained at plants A03 and E09, respectively. The pH for plant A03 was 3.4, while a value of 7.2 was determined for plant E09. The high BOD_5 and low pH for plant A03 suggests the presence of organic acids in the condensate stream.

3.3.2 DISTILLATION

There are two significant sources of wastewater from the distillation system: the beer still bottoms and rectifier bottoms. The bottom stream from the beer still, referred to as stillage, is routed to by-product recovery and, therefore, is discussed in a later section.

The amount of wastewater generated by concentrating the ethanol product ranges from 0.43 m^3 per 1,000 kg of grain processed for a grassroots ethanol-for-fuel facility (A06) to 1.4 m^3 per 1,000 kg of grain processed for a conventional ethanol facility such as A03 (308 Questionnaire, 1980). Plant A10 uses a cheese

Table 3-11

PERCENT VOLUME OF TOTAL UNTREATED EFFLUENT FOR GRAIN DISTILLERS WITH BY-PRODUCT RECOVERY

	Plant E09(1)	Plant E19(2)	Plant A03(3)
By-Product Recovery	77	50	66
Cooking/Mashing	11	36	14
Rectifying	10	7	28
Cleanup	2	7	1
Dehydration	-	-	1
Total	100%	100%	100%

Sources: (1) ESE, 1974, Reference 14
(2) Middlebrooks, Reference 15
(3) Industry Questionnaire Response

whey feedstock and produces 0.58 m^3 of wastewater per 1,000 kg of feedstock (308 Questionnaire, 1980). The volume of rectification wastewater is a function of the concentration of ethanol entering the rectifier and the source of energy (heat) used to separate the ethanol and water. When the rectifier feed is derived from the beer still, a 60 to 80 percent ethanol stream is concentrated to 95 percent in the rectifier. When purification columns are used, the feed to the rectifier may be only 10 to 20 percent ethanol (the beer still product is diluted in purifying columns) and likewise must be concentrated to 95 percent. Also, it is estimated that the use of direct steam injection rather than reboilers as a source of energy to accomplish the separation of water and ethanol can increase the wastewater volume from distillation by 20 percent (14).

Conventional analyses conducted for the rectifier bottom streams exhibited BOD_5 values for plants A03, A10, and E13 that were 1,440, 277, and 300 mg/l, respectively. The total suspended solids concentration for plants A03 and A10 were below the 1 mg/l detection limit, while the pH values were 4.7 and 6.2, respectively.

Priority pollutant analyses were conducted for the rectifying columns at plants A10 and A06, which integrates the dehydration and rectification processes. The priority organics detected at values greater than 10 ug/l were the same for both A06 and A10, these included methylene chloride, bis(2-ethylhexyl) phthalate, and phenolics (4AAP). The priority metals which were present at levels above their detection limit for both A10 and A06 included cadmium, copper, lead, and zinc. In addition, chromium and nickel were found only at plant A06.

3.3.3 DEHYDRATION

In typical dehydration schemes, the remaining water is removed from the 95 percent ethanol product via the bottom stream of the solvent stripping column and/or dehydration column. These streams are small, amounting to 0.002 m^3 per 1,000 kg of grain processed, and are independent of any processing variables (8).

The concentrations for BOD_5, TOC, TSS, pH, and phenolics for the solvent stripping column bottoms from plants A01 and A03 are presented in Table 3-12. The concentrations of these species in the stripping column bottoms stream are quite low in these parameters. Additional priority pollutant analyses at plant A01 demonstrated the only organic compound present was methylene chloride at 22 ug/l. The priority metals present at levels above their detection limits included chromium, copper, and zinc at 4.0, 6.0, and 10.0 ug/l, respectively. An analysis for benzene in the wastewater stream from the dehydration column and benzene stripping column at plant A03 exhibited concentrations of 59.4 ug/l and 5.7 ug/l, respectively (8).

Table 3-12

SOLVENT STRIPPING COLUMN BOTTOMS FROM DEHYDRATION SYSTEM DISCHARGE VALUES (mg/l)

	Plant A01	Plant A03
BOD_5	26.0	16.0
TOC	15.0	8.0
TSS	<1.0	1.0
pH	3.9	4.1
Phenolics	<0.01	*

*Not analyzed.

3.3.4 BY-PRODUCT RECOVERY

By-product recovery consists of concentrating the stillage from the bottom of the beer still in the centrifuges and evaporators, then drying the concentrated stillage in dryers. The evaporator condensate from this process is a major source of wastewater. In addition, the volume and quality of the condensate produced varies greatly. As Table 3-11 illustrates, evaporator condensate comprises 50 to 70 percent of the total volume of ethanol plant wastewater. The flow for evaporator condensate varies between 2.2 and 4.1 m^3 per 1,000 kg of grain processed. Alternate feedstocks such as cheese whey or sulfite liquor generate 1.6 m^3 per 1,000 kg of cheese whey and 0.78 m^3 per 1,000 kg of sulfite liquor, respectively (308 Questionnaire, 1980). Regardless of feedstock, this variation is a function of the stillage concentration entering the evaporators and the percent of stillage recycle to the cooker or conversion tank.

Another source of wastewater from by-product recovery is the blowdown stream from wet scrubbers; these are used to remove particulates from grain dryer exhaust gas. Plant E09 estimated that the load from this source constituted 37 percent of the total load from by-product recovery. Dry particulate collection devices such as cyclones are in use at most plants to eliminate this source of waste.

The sampling and analysis of evaporator condensate was done for four plants which differed in feedstock. The conventional parameter analyses demonstrated wide ranges for BOD_5 and pH. The BOD_5 varied from 628 mg/l for plant A06 (grain) to 4,835 mg/l for plant A07 (sulfite liquor). The molasses and cheese whey feedstock facilities had BOD_5's of approximately 2,550 mg/l. The pH ranged from 2.9 for plant A07 (sulfite liquor) to 7.95 for A10, the cheese whey facility. The high BOD_5 concentrations and low pH values imply that the contributing substances are primarily volatile organic acids.

A priority pollutant characterization of evaporator condensate for the four plants mentioned above is presented in Table 3-13. This table illustrates that few priority pollutant organic compounds were present. All the organics listed except methylene chloride, bis(2-ethylhexyl) phthalate, pentachlorophenol, phenol, toluene, and di-N-butyl phthalate were observed only once. Most of the priority metals were detected. All the metals except cadmium, chromium, copper, lead, nickel, and zinc were found only once above their detection limit.

3.3.5 WASH WATER

The risk of contamination from bacteria and other biological organisms which compete with the yeast and lower the alcohol yield have necessitated weekly cleanups and sterilization of the feedstock preparation vessels and fermenters. The amount of wash

Table 3-13

EVAPORATOR CONDENSATE CHARACTERIZATION: PRIORITY POLLUTANTS

Organics (ug/l)[1]	A06 (Grain)	A07 (Sulfite Liquor)	E02 (Molasses)	A10 (Cheese Whey)
acrolein	11	--	--	--
chlorobenzene	--	16	--	--
1,1,2-trichloroethane	--	15	--	--
1,2-dichloro propane	--	15	--	--
ethylbenzene	--	7.5	--	--
methylene chloride	34	54	17.5	150
pentachlorophenol	--	20.5	--	--
phenol	--	98	--	--
bis(2-ethylhexyl) phthalate	6.0	39	13.5	74
toluene	--	10	--	--
cyanide	--	20	--	--
di-N-butyl phthalate	--	--	10.5	--
tetrachloroethylene	16	--	--	--
Metals (ug/l)[2]				
antimony	--	2.3	--	--
arsenic	--	1.3	--	--
beryllium	1.0	--	--	--
cadmium	9.7	13	1.5	--
chromium	17	17.7	1.0	--
copper	862	15.7	9.5	80
lead	160	79	13.5	--
nickel	168	45	17	--
selenium	--	1.7	--	--
silver	--	1.3	--	--
zinc	36	74	26	118

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[1] Priority pollutant organics with at least one maximum concentration greater than 10 ug/l. Average concentrations are listed.

[2] Priority metals with at least one analysis above the detection limit for that element. Average concentrations are listed.

water generated during sterilization and cleanup and the waste load varies from plant to plant according to the final product purity requirements, operating procedure, plant management practices, types of equipment, and plant design. The amount of wash water produced for the seven ethanol plants tested ranged from 0.45 m^3 per 1,000 kg of grain processed to less than 0.04m^3 per 1,000 kg of grain processed of wash water at plant A06.

Priority pollutant analyses of the wash waters from plants A06, E09, and A10 yielded no toxic compounds present at concentrations higher than 10 ug/l. Conventional pollutant analyses showed BOD_5 concentrations ranging from 48 to 1,760 mg/l, TSS concentrations ranging from 63 to 1,180 mg/l, and pH values ranging from 4.0 to 12.0. Oil and grease was a significant pollutant parameter at plant E09, with an average value of 137 mg/l. Plants A06 and A10 had oil and grease values of less than 25 mg/l.

3.4 WASTEWATER CHARACTERIZATION

This section summarizes the analytical results obtained from the sampling programs and data collection efforts for the total plant untreated effluent. All the concentrations listed are absolute concentrations of the raw wastewater; no adjustment has been made for the species' presence in the plant intake water. If a parameter was reported at "not detected" it was assigned a value of zero for computational purposes. In cases where a parameter was never detected in any analyses, a dot appears in each of the columns to the right of the number of analyses.

Concentrations for metals were occasionally reported by the analytical laboratory as "detected less than X," where X equals some detection limit. In these cases, the exact concentration is unknown and the parameter is reported as being detected, but at a level less than the detection limit. For computational purposes, the method that has been used in the past by the Agency for quantifying the values reported as "detected less than X," where X equals some detection limit, is to represent the value as one-half of X.

Historically, the Agency has considered 10 ug/l as a realistic lower limit for detection of organic compounds. The total number of samples where a detected value of greater than 10 ug/l was found is indicated since these concentrations are "quantifiable levels." In regard to metals, the detection limit varies according to parameter and the laboratory that conducts the analyses. Therefore, the number of times a metal was detected above the particular analytical laboratory's detection limit is indicated.

The statistics used in this section include the minimum, median, mean, and maximum reported concentrations. The statistical values for median, minimum, and maximum are based on all the analyses performed. However, because the number of analyses performed varied from plant to plant, the mean concentration reported for a specific parameter is an average of the mean concentrations of each plant. For the statistical analysis, if a parameter was not detected in an analysis, it was given a concentration of zero and if the reported species concentration was "less than X," it was given a value of one-half of X.

The tables listing priority pollutant metals, cyanide, and asbestos also include the 90 percent value (90 percent of the detected values are below this concentration) and the standard deviation. The tables presenting data on conventional parameter's include the 95 and 99 percent values, as well as the standard deviation. Statistical percentages such as the 95 percent level were not calculated for priority pollutant organics and nonconventional parameters which lacked a significant number of detections.

3.4.1 ETHANOL PLANT UNTREATED EFFLUENT

The analytical results for priority pollutant organics, priority pollutant metals, conventional pollutants, and nonconventional pollutants are summarized in this section. These results represent the total combined untreated effluent from ethanol plants A01, A03, A06, A07, A10, E02, E08, and E09.

It was not possible to sample a combined untreated effluent stream at plant A06 or A10. For each parameter, the total raw wastewater value was calculated by taking a weighted average (flow rate basis) of the concentrations for each of the streams contributing to the total plant effluent. The weighted values were determined by flow ratios obtained from plant personnel in their responses to the 308 questionnaire.

Priority Pollutants

The analytical results for priority pollutant organics listed in micrograms per liter (ug/l) are presented in Table 3-14. Ten organics were found with at least one maximum concentration above 10 ug/l. Only five of these ten were present at two or more plants, these included bis(2-ethylhexyl) phthalate, chloroform, methylene chloride, pentachlorophenol, and phenol. The mean values for chloroform (27 ug/l) and phenol (33 ug/l) were significantly influenced by the high concentrations found at A07 and E02, respectively. For the remaining five organics found at levels above 10 ug/l, butyl benzyl phthalate, toluene, and trichloroethylene were found only at plant E09. Benzene and ethylbenzene were only present above the 10 ug/l level at plants A01 and E02, respectively.

Table 3-14

UNTREATED EFFLUENT ANALYSES SUMMARY
PRIORITY POLLUTANT ORGANICS

COMPOUND	TOTAL NUMBER SAMPLES	TOTAL NUMBER DETECTS	NUMBER DETECTS >10 UG/L	STATISTICS FOR SAMPLES ANALYZED CONCENTRATIONS IN UG/L			
				MIN	MEDIAN	MEAN	MAX
ACENAPHTHENE	23	1	0	0	0	0	0
ACENAPHTHYLENE	23	0	.	.	.	.	.
ACROLEIN	23	0	.	.	.	.	.
ACRYLONITRILE	23	0	.	.	.	.	.
ALDRIN	23	0	.	.	.	.	.
ANTHRACENE	23	4	0	0	0	0	2
BENZENE	23	18	3	0	1	65	1000
BENZIDENE	23	0	.	.	.	.	.
BENZO(A)ANTHRACENE	23	1	0	0	0	0	0
BENZO(A)PYRENE	23	0	.	.	.	.	.
BENZO(B)FLUORANTHENE	23	0	.	.	.	.	.
BENZO(G,H,I)PERYLENE	23	0	.	.	.	.	.
BENZO(K)FLUORANTHENE	23	0	.	.	.	.	.
BHC (LINDANE)-GAMMA	23	0	.	.	.	.	.
BHC-ALPHA	23	0	.	.	.	.	.
BHC-BETA	23	0	.	.	.	.	.
BHC-DELTA	23	0	.	.	.	.	.
BIS(CHLOROMETHYL) ETHER	23	0	.	.	.	.	.
BIS(2-CHLOROETHOXY) METHANE	23	0	.	.	.	.	.
BIS(2-CHLOROETHYL) ETHER	23	0	.	.	.	.	.
BIS(2-CHLOROISOPROPYL) ETHER	23	0	.	.	.	.	.
BIS(2-ETHYLHEXYL) PHTHALATE	23	18	11	0	9	18	72
BROMOFORM	23	0	.	.	.	.	.
BUTYL BENZYL PHTHALATE	23	6	5	0	0	13	220
CARBON TETRACHLORIDE	23	0	.	.	.	.	.
CHLORDANE	23	0	.	.	.	.	.
CHLOROBENZENE	23	0	.	.	.	.	.
CHLORODIBROMOMETHANE	23	0	.	.	.	.	.
CHLOROETHANE	23	0	.	.	.	.	.
CHLOROFORM	23	14	4	0	2	27	390

Table 3-14(Continued)

UNTREATED EFFLUENT ANALYSES SUMMARY
PRIORITY POLLUTANT ORGANICS

COMPOUND	TOTAL NUMBER SAMPLES	TOTAL NUMBER DETECTS	NUMBER DETECTS >10 UG/L	STATISTICS FOR SAMPLES ANALYZED CONCENTRATIONS IN UG/L			
				MIN	MEDIAN	MEAN	MAX
CHRYSENE	23	1	0	0	0	0	0
DI-N-BUTYL PHTHALATE	23	13	0	0	1	2	8
DI-N-OCTYL PHTHALATE	23	5	0	0	0	0	6
DIBENZO(A,H)ANTHRACENE	23	0	.	.	.	.	.
DICHLOROBROMOMETHANE	23	0	.	.	.	.	.
DICHLORODIFLUOROMETHANE	23	0	.	.	.	.	.
DIELDRIN	23	0	.	.	.	.	.
DIETHYL PHTHALATE	23	5	0	0	0	1	8
DIMETHYL PHTHALATE	23	0	.	.	.	.	.
ENDOSULFAN SULFATE	23	0	.	.	.	.	.
ENDOSULFAN-ALPHA	23	0	.	.	.	.	.
ENDOSULFAN-BETA	23	0	.	.	.	.	.
ENDRIN	23	0	.	.	.	.	.
ENDRIN ALDEHYDE	23	0	.	.	.	.	.
ETHYLBENZENE	23	4	1	0	0	1	11
FLUORANTHENE	23	0	.	.	.	.	.
FLUORENE	23	0	.	.	.	.	.
HEPTACHLOR	23	0	.	.	.	.	.
HEPTACHLOR EPOXIDE	23	0	.	.	.	.	.
HEXACHLOROBENZENE	23	0	.	.	.	.	.
HEXACHLOROBUTADIENE	23	0	.	.	.	.	.
HEXACHLOROCYCLOPENTADIENE	23	0	.	.	.	.	.
HEXACHLOROETHANE	23	0	.	.	.	.	.
INDENO(1,2,3-C,D)PYRENE	23	0	.	.	.	.	.
ISOPHORONE	23	0	.	.	.	.	.
METHYL BROMIDE	23	0	.	.	.	.	.
METHYL CHLORIDE	23	0	.	.	.	.	.
METHYLENE CHLORIDE (DICHLOROMETHANE)	23	20	18	0	19	30	99
N-NITROSODI-N-PROPYLAMINE	23	0	.	.	.	.	.
N-NITROSODIMETHYLAMINE	23	0	.	.	.	.	.
N-NITROSODIPHENYLAMINE	23	0	.	.	.	.	.

Table 3-14 (Continued)

UNTREATED EFFLUENT ANALYSES SUMMARY
PRIORITY POLLUTANT ORGANICS

COMPOUND	TOTAL NUMBER SAMPLES	TOTAL NUMBER DETECTS	NUMBER DETECTS >10 UG/L	STATISTICS FOR SAMPLES ANALYZED CONCENTRATIONS IN UG/L MIN	MEDIAN	MEAN	MAX
NAPHTHALENE	23	8	0	0	0	0	3
NITROBENZENE	23	0	.	.	.	.	.
PARACHLOROMETA CRESOL	22	0	.	.	.	.	.
PCB-1016 (AROCHLOR 1016)	23	0	.	.	.	.	.
PCB-1221 (AROCHLOR 1221)	23	0	.	.	.	.	.
PCB-1232 (AROCHLOR 1232)	23	0	.	.	.	.	.
PCB-1242 (AROCHLOR 1242)	23	0	.	.	.	.	.
PCB-1248 (AROCHLOR 1248)	23	0	.	.	.	.	.
PCB-1254 (AROCHLOR 1254)	23	0	.	.	.	.	.
PCB-1260 (AROCHLOR 1260)	23	0	.	.	.	.	.
PENTACHLOROPHENOL	23	4	3	0	0	4	47
PHENANTHRENE	23	4	0	0	0	0	2
PHENOL	23	16	11	0	8	33	190
PYRENE	23	1	0	0	0	0	0
TETRACHLOROETHYLENE	23	1	0	0	0	0	1
TOLUENE	23	20	6	0	4	10	94
TOXAPHENE	23	0	.	.	.	.	.
TRICHLOROETHYLENE	23	6	5	0	0	7	92
TRICHLOROFLUOROMETHANE	23	0	.	.	.	.	.
VINYL CHLORIDE	23	0	.	.	.	.	.
1,1-DICHLOROETHANE	23	0	.	.	.	.	.
1,1-DICHLOROETHYLENE	23	0	.	.	.	.	.
1,1,1-TRICHLOROETHANE	23	8	0	0	0	2	9
1,1,2-TRICHLOROETHANE	23	0	.	.	.	.	.
1,1,2,2-TETRACHLOROETHANE	23	0	.	.	.	.	.
1,2-DICHLOROBENZENE	23	0	.	.	.	.	.
1,2-DICHLOROETHANE	23	0	.	.	.	.	.
1,2-DICHLOROPROPANE	23	0	.	.	.	.	.
1,2-DIPHENYLHYDRAZINE	23	0	.	.	.	.	.
1,2-TRANS-DICHLOROETHYLENE	23	0	.	.	.	.	.

Table 3-14 (Continued)

UNTREATED EFFLUENT ANALYSES SUMMARY PRIORITY POLLUTANT ORGANICS

COMPOUND	TOTAL NUMBER SAMPLES	TOTAL NUMBER DETECTS	NUMBER DETECTS >10 UG/L	STATISTICS FOR SAMPLES ANALYZED CONCENTRATIONS IN UG/L MIN	MEDIAN	MEAN	MAX
1,2,3-TRICHLOROBENZENE	23	0	.	.	.	.	.
1,3-DICHLOROBENZENE	23	0	.	.	.	.	.
1,3-DICHLOROPROPENE	23	0	.	.	.	.	.
1,4-DICHLOROBENZENE	23	0	.	.	.	.	.
2-CHLOROETHYL VINYL ETHER (MIXED)	23	0	.	.	.	.	.
2-CHLORONAPHTHALENE	23	0	.	.	.	.	.
2-CHLOROPHENOL	23	0	.	.	.	.	.
2-NITROPHENOL	23	1	0	0	0	1	10
2,3,7,8-TETRACHLORODIBENZO-P-DIOXIN	23	0	.	.	.	.	.
2,4-DICHLOROPHENOL	23	0	.	.	.	.	.
2,4-DIMETHYLPHENOL	23	4	0	0	0	1	10
2,4-DINITROPHENOL	23	0	.	.	.	.	.
2,4-DINITROTOLUENE	23	0	.	.	.	.	.
2,4,6-TRICHLOROPHENOL	23	0	.	.	.	.	.
2,6-DINITROTOLUENE	23	0	.	.	.	.	.
3,3-DICHLOROBENZIDINE	23	0	.	.	.	.	.
4-BROMOPHENYL PHENYL ETHER	23	0	.	.	.	.	.
4-CHLOROPHENYL PHENYL ETHER	23	0	.	.	.	.	.
4-NITROPHENOL	23	0	.	.	.	.	.
4,4-DDD	23	0	.	.	.	.	.
4,4-DDE	23	0	.	.	.	.	.
4,4-DDT	23	0	.	.	.	.	.
4,6-DINITRO-O-CRESOL	23	0	.	.	.	.	.

All of the priority metals are listed in Table 3-15 and were detected at levels above their detection limit. The cadmium and lead analyses performed for the untreated effluent at plant E08 have been omitted from the table as the detection limits of the analytical laboratory for plant E08 were significantly higher for these compounds than those limits achievable at the other laboratories. Mercury was the only metal limited to a single facility, E08. The analyses for cyanide demonstrated only a single value above the detection limit, 10.5 ug/l at facility A10. The asbestos testing was performed at plants A06, A07, and E09. No chrysotile or fibrous asbestos greater than 5 micrometers was found at any of these three facilities.

Conventional Pollutants

The concentrations of conventional pollutants, listed as milligrams per liter (mg/l), are summarized in Table 3-16. In addition to the EPA Multimedia Sampling Program results, the daily monitoring information obtained from the sampled facilities as well as several other beverage alcohol plants (E06, E07, E15, E17, and E18) have been included. As mentioned earlier, the mean value reported for a specific parameter was determined by finding an average of all the plants' mean concentrations.

The BOD_5, total suspended solids (TSS), and oil and grease are all present at average concentrations of 1,405; 406; and 186 mg/l, respectively, which are much higher than those for typical domestic sewage. A wide range is evidenced for pH, which varies from 3 to 13.

Nonconventional Pollutant Parameters

All parameters which were tested that are not classified as conventional or priority pollutants are summarized in Tables 3-17 through 3-19 as nonconventional pollutants. The nonconventional metals are listed in Table 3-17. All of these metals, except bismuth, were detected one or more times above their detection limit. However, palladium and tellurium were only found at plant E09 while platinum was only present in the untreated effluent of plant A07. The remaining nonconventional metals were found at two or more facilities. Aluminum, calcium, magnesium, sodium, iron, and phosphorus were found at levels above 1 mg/l with values of 1.2; 550; 38.5; 1,060; 5.4; and 63.9, respectively.

Table 3-18 presents the results of the analyses for those compounds listed in Appendix C of the 1977 Consent Decree (Appendix C Compounds). The compounds present at levels greater than 10 ug/l, at least once, included: acetone, diethyl ether, methyl ethyl ketone, and the n-alkanes. The n-alkanes were found only at plant E08.

Table 3-15

UNTREATED EFFLUENT ANALYSES SUMMARY
PRIORITY POLLUTANT METALS, CYANIDE, AND ASBESTOS

COMPOUND	TOTAL NUMBER SAMPLES	TOTAL SAMPLES ABOVE DETECTION LIMIT	STATISTICS FOR SAMPLES ANALYZED CONCENTRATIONS IN UG/L					
			MIN	MEDIAN	MEAN	P90	MAX	STD
ANTIMONY (TOTAL)	23	6	1	3	4	5	10	2
ARSENIC (TOTAL)	23	9	1	2	3	8	8	2
BERYLLIUM (TOTAL)	23	5	1	1	1	5	8	2
CADMIUM (TOTAL)	17	12	1	4	8	15	17	6
CHROMIUM (TOTAL)	23	18	5	19	17	33	36	11
COPPER (TOTAL)	23	21	5	150	342	1019	1210	354
CYANIDE (TOTAL)	23	1	0	10	9	10	10	4
LEAD (TOTAL)	17	10	3	34	54	148	189	52
MERCURY (TOTAL)	23	5	0	0	0	1	1	0
NICKEL (TOTAL)	23	11	3	25	71	253	270	87
SELENIUM (TOTAL)	23	9	0	3	5	24	43	11
SILVER (TOTAL)	23	5	0	1	1	3	3	1
THALLIUM (TOTAL)	23	4	1	3	11	47	47	16
ZINC (TOTAL)	23	22	10	117	164	390	590	134
ASBESTOS (CHRYSOTILE) (>5 UM)	3	0	.	.	.	.	.	.
ASBESTOS (FIBROUS) (>5 UM)	3	0	.	.	.	.	.	.
ASBESTOS(CHRYSOTILE-FIBERS/LITER / 10E5)	3	1	0	0	1	2	2	1
ASBESTOS(TOTAL-FIBERS/LITER / 10E5)	3	3	5	33	243	690	690	388

Table 3-16

UNTREATED EFFLUENT ANALYSES SUMMARY
CONVENTIONAL POLLUTANTS

COMPOUND	TOTAL NUMBER SAMPLES	MIN	MEDIAN	STATISTICS FOR SAMPLES ANALYZED CONCENTRATIONS IN MG/L				
				MEAN	P95	P99	MAX	STD
BOD (TOTAL)	140	18	1025	1405	3043	5190	5220	910
COLIFORM (COLONIES/100ML)	21	0	500	2607	24E3	24E3	24E3	7459
OIL & GREASE	22	3	16	188	1453	1580	1580	366
PH (UNITS)	80	3	8	.	10	13	13	.
TOTAL SUSPENDED SOLIDS	184	17	305	406	1197	2868	3930	480

Table 3-17

UNTREATED EFFLUENT ANALYSES SUMMARY
NONCONVENTIONAL PARAMETERS

COMPOUND	TOTAL NUMBER SAMPLES	TOTAL SAMPLES ABOVE DETECTION LIMIT	STATISTICS FOR SAMPLES ANALYZED CONCENTRATIONS IN UG/L			
			MIN	MEDIAN	MEAN	MAX
ALUMINUM (TOTAL)	22	22	41	542	508	1243
BARIUM (TOTAL)	22	18	3	33	27	53
BISMUTH (TOTAL)	13	0	1	5	17	40
BORON (TOTAL)	22	18	5	85	175	567
CALCIUM (TOTAL)	22	22	890	40200	111581	550000
COBALT (TOTAL)	22	8	3	24	17	70
GOLD (TOTAL)	13	3	1	9	21	80
LITHIUM (TOTAL)	13	9	1	2	5	15
MAGNESIUM (TOTAL)	22	22	80	9775	11589	38500
MANGANESE (TOTAL)	22	22	7	61	161	994
MOLYBDENUM (TOTAL)	22	8	5	18	26	94
PALLADIUM (TOTAL)	13	2	1	5	7	20
PLATINUM (TOTAL)	13	3	1	12	62	150
SODIUM (TOTAL)	22	22	2054	103300	168698	1060000
TELLURIUM (TOTAL)	13	1	1	5	18	47
TIN (TOTAL)	22	12	4	57	84	300
TITANIUM (TOTAL)	22	16	2	8	8	17
TOTAL IRON	22	22	449	1860	2085	5423
TOTAL PHOSPHOROUS	16	16	70	3905	10575	63880
VANADIUM (TOTAL)	22	9	1	3	22	121
YTTRIUM (TOTAL)	22	8	2	7	12	50

Table 3-18

UNTREATED EFFLUENT ANALYSES SUMMARY
NONCONVENTIONAL PARAMETERS

				STATISTICS FOR SAMPLES ANALYZED CONCENTRATIONS IN UG/L			
COMPOUND	TOTAL NUMBER SAMPLES	TOTAL NUMBER DETECTS	NUMBER DETECTS >10 UG/L	MIN	MEDIAN	MEAN	MAX
ACETONE	8	6	3	0	6	10	23
ALPHA-TERPINEOL	3	0	.	.	.	.	.
BIPHENYL	2	0	.	.	.	.	.
CAMPHOR	3	0	.	.	.	.	.
CUMENE	3	0	.	.	.	.	.
DIBENZOFURAN	3	0	.	.	.	.	.
DIBUTYL AMINE	3	0	.	.	.	.	.
DIETHYL AMINE	3	0	.	.	.	.	.
DIETHYL ETHER	3	2	2	0	70	290	800
DIMETHYL AMINE	3	0	.	.	.	.	.
DIPHENYL AMINE	3	0	.	.	.	.	.
DIPHENYL ETHER	3	0	.	.	.	.	.
METHYL ETHYL KETONE	9	7	2	0	3	4	11
N-ALKANES	9	3	3	0	0	3	33
STYRENE	3	1	0	0	0	1	3

Table 3-19

UNTREATED EFFLUENT ANALYSES SUMMARY
NONCONVENTIONAL PARAMETERS

COMPOUND	TOTAL NUMBER SAMPLES	TOTAL NUMBER DETECTS	STATISTICS FOR SAMPLES ANALYZED CONCENTRATIONS IN mg/1			
			MIN	MEDIAN	MEAN	MAX
Chlorine (Total)	6	0	0	0	0	0
COD	22	22	260	1118	2618	6690
Dissolved Oxygen	22	22	0	2	4	14
Dissolved Solids	22	22	88	912	1664	5170
Kjeldahl Nitrogen (Total)	22	22	1	6	24	97
MO Alkalinity ($CACO_3$)	17	17	14	233	400	2180
NH_3-N (Ammonia)	22	15	0	8	21	94
Nitrite (Total)	9	4	0	0	0	0
Phosphate (PO_4)	6	6	1	1	2	5
Phenolics (4AAP)	23	22	.002	.060	.236	1.240
Residual Chlorine	3	0	0	0	0	0
Settleable Solids (ml/1)	22	10	0	0	4	27
Temperature (C)	15	15	20	36	34	44
Total Acidity ($CACO_3$)	18	18	3	61	176	680
Total Organic Carbon	22	22	46	358	847	2150
Total Solids	9	9	108	836	820	3270
Total Volatile Solids	21	21	65	287	1015	2480
Volatile Suspended Solids	2	2	92	122	122	152

Table 3-19 presents the remaining nonconventional parameters including those analyses conducted in the field. All the parameters listed had quantitative results reported except residual and total chlorine, which were either not present or present at levels below the detection limit of the analytical techniques. The high mean values of chemical oxygen demand (COD) and total organic carbon (TOC) at 2,618 mg/l and 852 mg/l, respectively; are consistent with the high BOD_5 concentrations reported in Table 3-16. Phenolics were found with a maximum concentration above 10 ug/l and were also present at two or more plants.

3.4.2 TREATED EFFLUENT

Three of the plants sampled in the EPA Multimedia Sampling Program had wastewater treatment systems which could provide an indication of the treatability of ethanol plant effluents, these included plants A03, E02, and E08. All three of these plants were sampled for priority, conventional, and nonconventional pollutants with a few exceptions. Appendix C compound analyses were not conducted on the treated effluent of plant E02. Also, one day's sampling for priority pollutant analyses at plant A03 is taken from the 1979 IERL-Ci study conducted by Radian Corporation.

Priority Pollutants

Table 3-20 summarizes the priority pollutant organic analyses conducted for ethanol plant treated effluent streams. The compounds found at least once with a maximum concentration above 10 ug/l include: bis(2-ethylhexyl) phthalate, chloroform, methylene chloride, phenol, and 2,4-dimethyl phenol. Only bis(2-ethylhexyl) phthalate and methylene chloride were present more than once, the mean concentrations of these two compounds were 40 ug/l and 11 ug/l, respectively.

The priority metal analyses which are summarized in Table 3-21 demonstrate that 10 of the priority metals were present one or more times above their analytical detection limit. As mentioned earlier, the lead and cadmium analyses for E08 have been excluded due to the much higher detection limit of the analytical labs for these parameters at that particular facility. Four metals were detected in the treated effluent at only one facility including antimony, lead, mercury, and selenium. The remaining six priority pollutant metals (arsenic, cadmium, nickel, chromium, copper, and zinc) were found at levels above their detection limit at two or more ethanol plants.

Conventional Pollutants

The analytical results for conventional parameters present in the treated effluent are summarized in Table 3-22. In addition to the data from plants A03, E02, and E08, data on the BOD_5

Table 3-20

TREATED EFFLUENT ANALYSES SUMMARY PRIORITY POLLUTANT ORGANICS

COMPOUND	TOTAL NUMBER SAMPLES	TOTAL NUMBER DETECTS	NUMBER DETECTS >10 UG/L	STATISTICS FOR SAMPLES ANALYZED CONCENTRATIONS IN UG/L			
				MIN	MEDIAN	MEAN	MAX
ACENAPHTHENE	11	0	.	.	.	.	.
ACENAPHTHYLENE	11	0	.	.	.	.	.
ACROLEIN	11	0	.	.	.	.	.
ACRYLONITRILE	11	0	.	.	.	.	.
ALDRIN	11	0	.	.	.	.	.
ANTHRACENE	11	0	.	.	.	.	.
BENZENE	11	3	0	0	0	0	1
BENZIDENE	11	0	.	.	.	.	.
BENZO(A)ANTHRACENE	11	0	.	.	.	.	.
BENZO(A)PYRENE	11	0	.	.	.	.	.
BENZO(B)FLUORANTHENE	11	0	.	.	.	.	.
BENZO(G,H,I)PERYLENE	11	0	.	.	.	.	.
BENZO(K)FLUORANTHENE	11	0	.	.	.	.	.
BHC (LINDANE)-GAMMA	11	0	.	.	.	.	.
BHC-ALPHA	11	0	.	.	.	.	.
BHC-BETA	11	0	.	.	.	.	.
BHC-DELTA	11	0	.	.	.	.	.
BIS(CHLOROMETHYL) ETHER	11	0	.	.	.	.	.
BIS(2-CHLOROETHOXY) METHANE	11	0	.	.	.	.	.
BIS(2-CHLOROETHYL) ETHER	11	0	.	.	.	.	.
BIS(2-CHLOROISOPROPYL) ETHER	11	0	.	.	.	.	.
BIS(2-ETHYLHEXYL) PHTHALATE	11	5	2	0	0	40	310
BROMOFORM	11	0	.	.	.	.	.
BUTYL BENZYL PHTHALATE	11	0	.	.	.	.	.
CARBON TETRACHLORIDE	11	0	.	.	.	.	.
CHLORDANE	11	0	.	.	.	.	.
CHLOROBENZENE	11	0	.	.	.	.	.

Table 3-20 (Continued)

TREATED EFFLUENT ANALYSES SUMMARY
PRIORITY POLLUTANT ORGANICS

COMPOUND	TOTAL NUMBER SAMPLES	TOTAL NUMBER DETECTS	NUMBER DETECTS >10 UG/L	STATISTICS FOR SAMPLES ANALYZED CONCENTRATIONS IN UG/L			
				MIN	MEDIAN	MEAN	MAX
CHLORODIBROMOMETHANE	11	0	.	.	.	.	.
CHLOROETHANE	11	0	.	.	.	.	.
CHLCROFORM	11	2	1	0	0	7	42
CHRYSENE	11	0	.	.	.	.	.
DI-N-BUTYL PHTHALATE	11	3	0	0	0	2	8
DI-N-OCTYL PHTHALATE	11	0	.	.	.	.	.
DIBENZO(A,H)ANTHRACENE	11	0	.	.	.	.	.
DICHLOROBROMOMETHANE	11	0	.	.	.	.	.
DICHLORODIFLUOROMETHANE	11	0	.	.	.	.	.
DIELDRIN	11	0	.	.	.	.	.
DIETHYL PHTHALATE	11	2	0	0	0	1	8
DIMETHYL PHTHALATE	11	0	.	.	.	.	.
ENDOSULFAN SULFATE	11	0	.	.	.	.	.
ENDOSULFAN-ALPHA	11	0	.	.	.	.	.
ENDOSULFAN-BETA	11	0	.	.	.	.	.
ENDRIN	11	0	.	.	.	.	.
ENDRIN ALDEHYDE	11	0	.	.	.	.	.
ETHYLBENZENE	11	0	.	.	.	.	.
FLUORANTHENE	11	0	.	.	.	.	.
FLUORENE	11	0	.	.	.	.	.
HEPTACHLOR	11	0	.	.	.	.	.
HEPTACHLOR EPOXIDE	11	0	.	.	.	.	.
HEXACHLOROBENZENE	11	0	.	.	.	.	.
HEXACHLOROBUTADIENE	11	0	.	.	.	.	.
HEXACHLOROCYCLOPENTADIENE	11	0	.	.	.	.	.
HEXACHLOROETHANE	11	0	.	.	.	.	.
INDENO(1,2,3-C,D)PYRENE	11	0	.	.	.	.	.

Table 3-20 (Continued)

TREATED EFFLUENT ANALYSES SUMMARY
PRIORITY POLLUTANT ORGANICS

COMPOUND	TOTAL NUMBER SAMPLES	TOTAL NUMBER DETECTS	NUMBER DETECTS >10 UG/L	STATISTICS FOR SAMPLES ANALYZED CONCENTRATIONS IN UG/L			
				MIN	MEDIAN	MEAN	MAX
ISOPHORONE	11	0	.	.	.	.	.
METHYL BROMIDE	11	0	.	.	.	.	.
METHYL CHLORIDE	11	0	.	.	.	.	.
METHYLENE CHLORIDE (DICHLOROMETHANE)	11	3	2	0	0	11	41
N-NITROSODI-N-PROPYLAMINE	11	0	.	.	.	.	.
N-NITROSODIMETHYLAMINE	11	0	.	.	.	.	.
N-NITROSODIPHENYLAMINE	11	0	.	.	.	.	.
NAPHTHALENE	11	0	.	.	.	.	.
NITROBENZENE	11	0	.	.	.	.	.
PARACHLOROMETA CRESOL	11	0	.	.	.	.	.
PCB-1016 (AROCHLOR 1016)	11	0	.	.	.	.	.
PCB-1221 (AROCHLOR 1221)	11	0	.	.	.	.	.
PCB-1232 (AROCHLOR 1232)	11	0	.	.	.	.	.
PCB-1242 (AROCHLOR 1242)	11	0	.	.	.	.	.
PCB-1248 (AROCHLOR 1248)	11	0	.	.	.	.	.
PCB-1254 (AROCHLOR 1254)	11	0	.	.	.	.	.
PCB-1260 (AROCHLOR 1260)	11	0	.	.	.	.	.
PENTACHLOROPHENOL	11	0	.	.	.	.	.
PHENANTHRENE	11	0	.	.	.	.	.
PHENOL	11	1	1	0	0	2	15
PYRENE	11	0	.	.	.	.	.
TETRACHLOROETHYLENE	11	0	.	.	.	.	.
TOLUENE	11	2	0	0	0	1	5
TOXAPHENE	11	0	.	.	.	.	.
TRICHLOROETHYLENE	11	0	.	.	.	.	.
TRICHLOROFLUOROMETHANE	11	0	.	.	.	.	.

Table 3-20 (Continued)

TREATED EFFLUENT ANALYSES SUMMARY
PRIORITY POLLUTANT ORGANICS

COMPOUND	TOTAL NUMBER SAMPLES	TOTAL NUMBER DETECTS	NUMBER DETECTS >10 UG/L	STATISTICS FOR SAMPLES ANALYZED CONCENTRATIONS IN UG/L			
				MIN	MEDIAN	MEAN	MAX
VINYL CHLORIDE	11	0	.	.	.	.	.
1,1-DICHLOROETHANE	11	0	.	.	.	.	.
1,1-DICHLOROETHYLENE	11	0	.	.	.	.	.
1,1,1-TRICHLOROETHANE	11	2	0	0	0	2	5
1,1,2-TRICHLOROETHANE	11	0	.	.	.	.	.
1,1,2,2-TETRACHLOROETHANE	11	0	.	.	.	.	.
1,2-DICHLOROBENZENE	11	0	.	.	.	.	.
1,2-DICHLOROETHANE	11	0	.	.	.	.	.
1,2-DICHLOROPROPANE	11	0	.	.	.	.	.
1,2-DIPHENYLHYDRAZINE	11	0	.	.	.	.	.
1,2-TRANS-DICHLOROETHYLENE	11	0	.	.	.	.	.
1,2,3-TRICHLOROBENZENE	11	0	.	.	.	.	.
1,3-DICHLOROBENZENE	11	0	.	.	.	.	.
1,3-DICHLOROPROPENE	11	0	.	.	.	.	.
1,4-DICHLOROBENZENE	11	0	.	.	.	.	.
2-CHLOROETHYL VINYL ETHER (MIXED)	11	0	.	.	.	.	.
2-CHLORONAPHTHALENE	11	0	.	.	.	.	.
2-CHLOROPHENOL	11	0	.	.	.	.	.
2-NITROPHENOL	11	0	.	.	.	.	.
2,3,7,8-TETRACHLORODIBENZO-P-DIOXIN	11	0	.	.	.	.	.
2,4-DICHLOROPHENOL	11	0	.	.	.	.	.
2,4-DIMETHYLPHENOL	11	1	1	0	0	4	21
2,4-DINITROPHENOL	11	0	.	.	.	.	.
2,4-DINITROTOLUENE	11	0	.	.	.	.	.
2,4,6-TRICHLOROPHENOL	11	0	.	.	.	.	.
2,6-DINITROTOLUENE	11	0	.	.	.	.	.
3,3-DICHLOROBENZIDINE	11	0	.	.	.	.	.

Table 3-20 (Continued)

TREATED EFFLUENT ANALYSES SUMMARY
PRIORITY POLLUTANT ORGANICS

COMPOUND	TOTAL NUMBER SAMPLES	TOTAL NUMBER DETECTS	NUMBER DETECTS >10 UG/L	STATISTICS FOR SAMPLES ANALYZED CONCENTRATIONS IN UG/L			
				MIN	MEDIAN	MEAN	MAX
4-BROMOPHENYL PHENYL ETHER	11	0	.	.	.	.	.
4-CHLOROPHENYL PHENYL ETHER	11	0	.	.	.	.	.
4-NITROPHENOL	11	0	.	.	.	.	.
4,4-DDD	11	0	.	.	.	.	.
4,4-DDE	11	0	.	.	.	.	.
4,4-DDT	11	0	.	.	.	.	.
4,6-DINITRO-O-CRESOL	11	0	.	.	.	.	.

Table 3-21

TREATED EFFLUENT ANALYSES SUMMARY
PRIORITY POLLUTANT METALS AND CYANIDE

COMPOUND	TOTAL NUMBER SAMPLES	TOTAL SAMPLES ABOVE DETECTION LIMIT	STATISTICS FOR SAMPLES ANALYZED CONCENTRATIONS IN UG/L					
			MIN	MEDIAN	MEAN	P90	MAX	STD
ANTIMONY (TOTAL)	9	1	3	3	3	4	5	1
ARSENIC (TOTAL)	9	6	0	2	2	9	9	3
BERYLLIUM (TOTAL)	9	0	1	5	2	5	5	2
CADMIUM (TOTAL)	3	3	0	5	4	10	10	5
CHROMIUM (TOTAL)	9	9	1	20	18	50	50	14
COPPER (TOTAL)	9	8	5	30	249	680	680	218
CYANIDE (TOTAL)	9	0	0	0	7	10	10	5
LEAD (TOTAL)	3	2	3	67	36	71	71	38
MERCURY (TOTAL)	9	2	0	0	0	1	1	0
NICKEL (TOTAL)	9	3	0	15	95	277	277	106
SELENIUM (TOTAL)	9	4	0	2	7	43	43	17
SILVER (TOTAL)	9	0	0	1	1	3	3	1
THALLIUM (TOTAL)	9	0	1	2	9	25	25	10
ZINC (TOTAL)	9	7	5	38	54	115	115	37

Table 3-22

TREATED EFFLUENT ANALYSES SUMMARY
CONVENTIONAL POLLUTANTS

COMPOUND	TOTAL NUMBER SAMPLES	MIN	MEDIAN	STATISTICS FOR SAMPLES ANALYZED CONCENTRATIONS IN MG/L				
				MEAN	P95	P99	MAX	STD
BOD (TOTAL)	389	1	13	28	74	115	175	23
COLIFORM (COLONIES/100ML)	93	0	0	1121	2400	14E4	14E4	15E3
OIL & GREASE	9	0	15	139	427	427	427	161
PH (UNITS)	378	8	8	.	8	9	9	.
TOTAL SUSPENDED SOLIDS	288	1	29	49	100	180	200	33

(total), fecal coliform, oil and grease, total suspended solids (TSS) concentrations, and pH values for this table were obtained from the 308 Questionnaire responses that were received from the seven beverage alcohol facilities (plants E05, E06, E07, E13, E15, E17, and E18).

Both the BOD_5 and total suspended solids concentrations have demonstrated significant improvement over the untreated effluent concentration, with mean values of 26 mg/l for BOD_5 and 49 mg/l for TSS. The pH values for the treated effluent are all within the range of 6 to 9.

Nonconventional Pollutant Parameters

Tables 3-23 through 3-25 present the analytical results for nonconventional pollutant parameters in the treated effluent from plants E02 and E08. The nonconventional metals (Table 3-23) which were not present at concentration levels above their analytical detection limit were bismuth, palladium, platinum, and tellurium. Also, four of the nonconventional metals were found only at plant E02; these metals included molybdenum, tin, vanadium, and yttrium. Aluminum, calcium, magnesium, sodium, and iron were found at levels above 1 mg/l with values of 2.9, 165, 3.7, 50.2, and 2.6 mg/l, respectively.

The Appendix C compounds for plant E02 are summarized in Table 3-24. The only compound found above 10 ug/l was acetone at a concentration of 43 ug/l.

Finally, the remaining nonconventional parameters are summarized in Table 3-25. The average values for COD and TOC were reduced from 2,618 mg/l and 852 mg/l in the untreated effluent to 460 mg/l and 182 mg/l, respectively.

3.5 WASTEWATER POLLUTANTS OF CONCERN

The Agency has studied ethanol-for-fuel wastewaters to determine the presence or absence of toxic, conventional, and selected nonconventional pollutants.

One hundred and twenty-nine toxic pollutants (known as the 129 priority pollutants) were studied pursuant to the requirements of the Clean Water Act of 1977 (CWA). These pollutant parameters, which were listed in Table 3-2, are members of the 65 classes of toxic pollutants referred to as Table 1 in Section 307(a)(1) of the CWA. The five conventional pollutants identified in Section 304(a) of the CWA were listed in Table 3-3. The nonconventional parameters which were presented in Table 3-4 include, but are not limited to, a group of Agency-selected nontoxic metals and the species listed in Appendix C of the 1976 Consent Decree.

Table 3-23

TREATED EFFLUENT ANALYSES SUMMARY
NONCONVENTIONAL PARAMETERS

COMPOUND	TOTAL NUMBER SAMPLES	TOTAL SAMPLES ABOVE DETECTION LIMIT	STATISTICS FOR SAMPLES ANALYZED CONCENTRATIONS IN UG/L					
			MIN	MEDIAN	MEAN	P90	MAX	STD
ALUMINUM (TOTAL)	8	8	452	5050	3253	8100	8100	2924
BARIUM (TOTAL)	8	6	5	24	26	70	70	21
BISMUTH (TOTAL)	2	0	40	40	40	40	40	0
BORON (TOTAL)	8	4	5	23	138	265	265	108
CALCIUM (TOTAL)	8	8	50800	62524	105529	529000	529000	165481
COBALT (TOTAL)	8	4	11	25	28	60	60	18
GOLD (TOTAL)	2	2	50	55	55	60	60	7
LITHIUM (TOTAL)	2	1	2	2	2	3	3	1
MAGNESIUM (TOTAL)	8	8	12200	18950	16079	23500	23500	3741
MANGANESE (TOTAL)	8	8	40	284	185	504	504	140
MOLYBDENUM (TOTAL)	8	2	19	50	41	75	75	23
PALLADIUM (TOTAL)	2	0	20	20	20	20	20	0
PLATINUM (TOTAL)	2	0	150	150	150	150	150	0
SODIUM (TOTAL)	8	8	200000	213947	247582	352688	352688	50244
TELLURIUM (TOTAL)	2	0	35	35	35	35	35	0
TIN (TOTAL)	8	2	22	300	168	300	300	124
TITANIUM (TOTAL)	8	4	2	4	6	9	9	3
TOTAL IRON	8	8	225	704	2935	7782	7782	2584
TOTAL PHOSPHOROUS	2	2	811	995	995	1180	1180	261
VANADIUM (TOTAL)	8	2	3	3	51	101	101	45
YTTRIUM (TOTAL)	8	2	7	50	29	50	50	20

Table 3-24

TREATED EFFLUENT ANALYSES SUMMARY
NONCONVENTIONAL PARAMETERS

COMPOUND	TOTAL NUMBER SAMPLES	TOTAL NUMBER DETECTS	NUMBER DETECTS >10 UG/L	STATISTICS FOR SAMPLES ANALYZED CONCENTRATIONS IN UG/L			
				MIN	MEDIAN	MEAN	MAX
ACETONE	2	2	1	7	25	25	43
ALPHA-TERPINEOL	2	0	.	.	.	.	.
BIPHENYL	2	0	.	.	.	.	.
CAMPHOR	2	0	.	.	.	.	.
CUMENE	2	0	.	.	.	.	.
DIBENZOFURAN	2	0	.	.	.	.	.
DIBUTYL AMINE	2	0	.	.	.	.	.
DIETHYL AMINE	2	0	.	.	.	.	.
DIETHYL ETHER	2	0	.	.	.	.	.
DIMETHYL AMINE	2	0	.	.	.	.	.
DIPHENYL AMINE	2	0	.	.	.	.	.
DIPHENYL ETHER	2	0	.	.	.	.	.
METHYL ETHYL KETONE	2	2	0	3	4	4	6
N-ALKANES	2	0	.	.	.	.	.
STYRENE	2	0	.	.	.	.	.

Table 3-25

TREATED EFFLUENT ANALYSES SUMMARY
NONCONVENTIONAL PARAMETERS

COMPOUND	TOTAL NUMBER SAMPLES	TOTAL NUMBER DETECTS	STATISTICS FOR SAMPLES ANALYZED CONCENTRATIONS IN mg/1			
			MIN	MEDIAN	MEAN	MAX
COD	8	8	10	95	460	1140
Dissolved Oxygen	8	8	0	0	0	0
Dissolved Solids	8	8	416	836	1153	1810
Kjeldahl Nitrogen (Total)	8	8	3	10	7	14
MO Alkalinity ($CACO_3$)	8	8	251	291	428	869
NH_3-N (Ammonia)	8	6	1	1	1	2
Phosphate (PO_4)	6	6	1	5	6	14
Phenolics (4AAP)	9	6	0	0	.002	.015
Settleable Solids (ml/1)	8	1	0	0	0	1
Temperature (C)	8	8	13	17	22	30
Total Acidity ($CACO_3$)	7	7	10	17	34	103
Total Organic Carbon	8	8	28	30	182	486
Total Solids	6	6	848	892	899	977
Total Volatile Solids	8	8	0	97	393	820
Volatile Suspended Solids	3	3	42	45	44	46

A review of environmental regulations reveals that no federal regulations specifically apply to the effluents from either ethanol-for-fuel facilities or beverage alcohol facilities. In the absence of effluent guidelines, National Pollutant Discharge Elimination System (NPDES) permits have been issued to distillers based on "best professional judgment," under authority of Section 402(a)(1) of the Federal Water Pollution Control Act.

The EPA regional offices and state agencies have typically regulated suspended solids (TSS), biological oxygen demand (BOD_5) and pH for beverage alcohol facilities based on best professional judgment. From this study these parameters have also been selected as those potentially requiring reduction or control before discharge based on amount of discharge, treatability, costs and treatment technology.

Total Suspended Solids

Total suspended solids is a measure of the suspended material that can be removed from the wastewater by laboratory filtration, but does not include coarse or floating matter than can be readily screened or settled out. Generally, suspended solids include both organic and inorganic materials. The inorganic components include sand, silt, and clay. The organic fraction includes such materials as grease, oil, fibers, and various materials from sewers.

The suspended solids from an ethanol facility would most likely be organic in nature such as entrained fibers and insoluble protein material from feedstock preparation, by-product recovery, or plant wash waters. The analytical results from a number of ethanol facilities demonstrate a variation in the TSS concentration from 17 mg/l to 3,930 mg/l in the untreated effluent.

Biochemical Oxygen Demand

Biochemical oxygen demand is a measure of the oxygen consuming capabilities of organic matter. Materials which may contribute to BOD include: carbonaceous organic materials usable as a food source by aerobic organisms; oxidizable nitrogen derived from nitrites, ammonia, and organic nitrogen compounds which serve as food for specific bacteria; and certain chemically oxidizable materials such as ferrous iron, sulfides, sulfite, etc., which will react with dissolved oxygen or which are metabolized by bacteria.

The raw wastewater from an ethanol facility has a mean BOD_5 concentration (total) of 1,405 mg/l. Approximately 80 percent of this loading is dissolved organic materials. The high concentration of BOD_5, approximately seven times normal domestic sewage, requires that this parameter be reduced before discharge.

pH

Although not a specific pollutant, pH is related to the acidity or alkalinity of a wastewater stream. It is not a linear or direct measure of either; however, it may be properly used to control both excess acidity and excess alkalinity in water. The term pH describes the hydrogen ion-hydroxyl ion balance in water.

Data from the sampling program indicate a pH range of 3 to 13. Because extremes of pH or rapid pH changes can stress secondary biological treatment systems or kill aquatic life, this parameter must be controlled.

Other Pollutants

The Settlement Agreement in Natural Resources Defense Council, Incorporated vs. Train, 8 ERC 2120 (D.D.C. 1976), modified March 1979, which precedes the CWA, provides for the exclusion of particular pollutants, categories, and subcategories. The ethanol-for-fuel industry is not one of the 21 industries included in the Settlement Agreement and the provisions of this agreement do not necessarily pertain to the ethanol-for-fuel industry. However, the pollutant exclusion criteria developed are logical and reasonable means for determining whether parameters should be omitted from regulation. Therefore while EPA is not developing regulations for this industry, these criteria (summarized in Table 3-26) will be considered along with other criteria in the determination of pollutants of concern for the ethanol-for-fuel industry.

All of the priority pollutants and nonconventional pollutant parameters are not among the pollutants of concern for this industry for reasons discussed below. In addition, two conventional pollutants (fecal coliform and oil and grease) have been excluded as they are process and plant specific.

Exclusion of Priority Organics

Pollutants Not Detected by Approved Analytical Methods

Historically, the Agency has determined the detection limit for organic priority pollutants to be 10 ug/l. This level is the minimum concentration at which the signal-to-noise ratio was of sufficient magnitude to give a quantifiable value for the specie concentration. Therefore, pollutants that are detected concentrations equal to or less than 10 ug/l as well as pollutants not detected in any stream can be eliminated from regulation (Criterion 3). The compounds detected at values greater than 10 ug/l in the untreated effluent are presented in Table 3-27.

Table 3-26

SETTLEMENT AGREEMENT EXCLUSION CRITERIA

1. Equal or more stringent protection is already provided by EPA's guidelines and standards under the Act.

2. The pollutant is present in the effluent discharge solely as a result of its presence in the intake water to the production process.

3. The pollutant is not detectable in the effluent within the category by approved analytical methods or methods representing the state-of-the-art capabilities. This includes cases in which the pollutant is present solely as a result of contamination during sampling and analysis. (Contamination is determined by the species presence in the method and control blanks.)

4. The pollutant is detected in only a small number of sources within the category and is uniquely related to only those sources.

5. The pollutant is present only in trace amounts and is neither causing nor likely to cause toxic effects.

6. The pollutant is present in amounts too small to be effectively reduced by known technologies.

7. The pollutant is effectively controlled by the technologies upon which other effluent limitations and guidelines are based.

Table 3-27

TOXIC ORGANIC POLLUTANTS FOUND IN UNTREATED EFFLUENT FROM ETHANOL PLANTS (ug/l)

Pollutant	Total Number Samples	Total Number Detects	Mean	Max
benzene	23	16	65	1,000
bis phthalate	23	18	18	72
butyl benzyl phthalate	23	6	13	220
chloroform	23	14	27	390
ethylbenzene	23	4	1	11
methylene chloride	23	20	30	99
pentachlorophenol	23	4	4	47
phenol	23	16	33	190
toluene	23	20	10	94
trichloroethylene	23	6	7	92

Pollutants Present Due to Contamination

It is known that during sample collection, automatic composite samplers were equipped with polyvinyl chloride (Tygon) tubing or original manufacturer-supplied tubing. Phthalates are widely used as plasticizers to ensure that the Tygon tubing remains soft and flexible (16,17). These compounds, added during manufacturing, have a tendency to migrate to the surface of the tubing and leach into water passing through the sampler tubing.

Laboratory experiments have been performed to determine if phthalates and other priority pollutants could be leached from tubing used on composite samplers (18). The types of tubing used in these experiments were clear tubing supplied with the sampler at the time of purchase and Tygon S-50-HL, Class VI. Results of the analyses of the extracts representing the original and replacement Tygon tubing are summarized in Table 3-28. The data indicate that both types contain bis phthalate, and the original tubing leachate also had high concentrations of phenol.

To verify the actual presence of toxic pollutants in the ethanol facility effluent streams, an analysis of field and lab contamination was conducted. This was accomplished by the collection of method and control blanks. The results of these analyses are presented in Table 3-29. The method and control blank analyses demonstrate high concentrations (maximum = 190 ug/l) of bis phthalate; however, phenol was not detected in any of the other 26 samples. Therefore, bis phthalate is excluded on the basis of contamination, while phenol is not.

Two volatile organic compounds were detected as a result of the analyses of grab samples: methylene chloride and ethylbenzene. The volatile nature of these compounds suggests contamination as a possible source, especially considering the relatively low concentrations detected in the samples (mean values of 6 ug/l and 1 ug/l for methylene chloride and ethylbenzene, respectively). Also, these compounds may be found in the laboratory as solvents, extraction agents, or aerosol propellants. Thus, the presence and/or use of the compounds in the laboratory may be responsible for sample contamination. This type of contamination has been previously addressed in another study (19). In a review of a set of volatile organic blank analytical data from this study, inadvertent contamination was shown to have occurred; the prominent compounds being methylene chloride and ethylbenzene. On the basis of this study, methylene chloride and ethylbenzene were attributed to contamination and not selected for regulation.

Table 3-28

TUBING LEACHING ANALYSIS RESULTS

Component	Micrograms/Liter	
	Original ISCO	Tygon
Bis (2-ethylhexyl) Phthalate		
Acid Extract	915	N.D.
Base-Neutral Extract	2,070	885
Phenol		
Acid Extract	19,650	N.D.
Base-Neutral Extract	N.D.	N.D.

N.D. - Not Detected

Table 3-29

CONTROL AND METHOD BLANKS ANALYSES
PRIORITY POLLUTANT ORGANICS

COMPOUND	TOTAL NUMBER SAMPLES	TOTAL NUMBER DETECTS	NUMBER DETECTS >10 UG/L	STATISTICS FOR SAMPLES ANALYZED CONCENTRATIONS IN UG/L			
				MIN	MEDIAN	MEAN	MAX
ACENAPHTHENE	28	1	0	1	1	1	1
ACENAPHTHYLENE	28	0	.	.	.	.	.
ACROLEIN	28	0	.	.	.	.	.
ACRYLONITRILE	28	1	1	43	43	43	43
ALDRIN	28	0	.	.	.	.	.
ANTHRACENE	28	2	0	2	2	2	2
BENZENE	28	13	0	1	1	2	5
BENZIDENE	28	0	.	.	.	.	.
BENZO(A)ANTHRACENE	28	1	0	2	2	2	2
BENZO(A)PYRENE	28	0	.	.	.	.	.
BENZO(B)FLUORANTHENE	28	0	.	.	.	.	.
BENZO(G,H,I)PERYLENE	28	0	.	.	.	.	.
BENZO(K)FLUORANTHENE	28	0	.	.	.	.	.
BHC (LINDANE)-GAMMA	28	0	.	.	.	.	.
BHC-ALPHA	28	0	.	.	.	.	.
BHC-BETA	28	0	.	.	.	.	.
BHC-DELTA	28	0	.	.	.	.	.
BIS(CHLOROMETHYL) ETHER	27	0	.	.	.	.	.
BIS(2-CHLOROETHOXY) METHANE	28	0	.	.	.	.	.
BIS(2-CHLOROETHYL) ETHER	28	0	.	.	.	.	.
BIS(2-CHLOROISOPROPYL) ETHER	28	0	.	.	.	.	.
BIS(2-ETHYLHEXYL) PHTHALATE	28	14	9	2	24	39	190
BROMOFORM	28	1	0	5	5	5	5
BUTYL BENZYL PHTHALATE	28	1	0	2	2	2	2
CARBON TETRACHLORIDE	28	0	.	.	.	.	.
CHLORDANE	28	0	.	.	.	.	.
CHLOROBENZENE	28	0	.	.	.	.	.
CHLORODIBROMOMETHANE	28	0	.	.	.	.	.
CHLOROETHANE	28	0	.	.	.	.	.
CHLOROFORM	28	0	.	.	.	.	.
CHRYSENE	28	1	0	2	2	2	2

Table 3-29 (Continued)

CONTROL AND METHOD BLANKS ANALYSES
PRIORITY POLLUTANT ORGANICS

COMPOUND	TOTAL NUMBER SAMPLES	TOTAL NUMBER DETECTS	NUMBER DETECTS >10 UG/L	STATISTICS FOR SAMPLES ANALYZED CONCENTRATIONS IN UG/L			
				MIN	MEDIAN	MEAN	MAX
DI-N-BUTYL PHTHALATE	26	10	0	2	5	5	9
DI-N-OCTYL PHTHALATE	26	3	0	1	1	1	2
DIBENZO(A,H)ANTHRACENE	26	0	.	.	.	.	.
DICHLOROBROMOMETHANE	28	0	.	.	.	.	.
DICHLORODIFLUOROMETHANE	28	0	.	.	.	.	.
DIELDRIN	26	0	.	.	.	.	.
DIETHYL PHTHALATE	26	4	0	1	2	2	5
DIMETHYL PHTHALATE	26	0	.	.	.	.	.
ENDOSULFAN SULFATE	26	0	.	.	.	.	.
ENDOSULFAN-ALPHA	26	0	.	.	.	.	.
ENDOSULFAN-BETA	26	0	.	.	.	.	.
ENDRIN	26	0	.	.	.	.	.
ENDRIN ALDEHYDE	26	0	.	.	.	.	.
ETHYLBENZENE	28	2	0	4	5	5	5
FLUORANTHENE	26	0	.	.	.	.	.
FLUORENE	26	0	.	.	.	.	.
HEPTACHLOR	26	0	.	.	.	.	.
HEPTACHLOR EPOXIDE	26	0	.	.	.	.	.
HEXACHLOROBENZENE	26	0	.	.	.	.	.
HEXACHLOROBUTADIENE	26	0	.	.	.	.	.
HEXACHLOROCYCLOPENTADIENE	26	0	.	.	.	.	.
HEXACHLOROETHANE	26	0	.	.	.	.	.
INDENO(1,2,3-C,D)PYRENE	26	0	.	.	.	.	.
ISOPHORONE	26	0	.	.	.	.	.
METHYL BROMIDE	28	1	0	5	5	5	5
METHYL CHLORIDE	28	1	0	5	5	5	5
METHYLENE CHLORIDE (DICHLOROMETHANE)	28	27	24	5	88	257	1200
N-NITROSODI-N-PROPYLAMINE	26	0	.	.	.	.	.
N-NITROSODIMETHYLAMINE	28	0	.	.	.	.	.
N-NITROSODIPHENYLAMINE	28	1	0	1	1	1	1
NAPHTHALENE	26	3	0	2	2	2	3

Table 3-29 (Continued)

CONTROL AND METHOD BLANKS ANALYSES
PRIORITY POLLUTANT ORGANICS

COMPOUND	TOTAL NUMBER SAMPLES	TOTAL NUMBER DETECTS	NUMBER DETECTS >10 UG/L	STATISTICS FOR SAMPLES ANALYZED CONCENTRATIONS IN UG/L			
				MIN	MEDIAN	MEAN	MAX
NITROBENZENE	28	0	.	.	.	.	.
PARACHLOROMETA CRESOL	28	0	.	.	.	.	.
PCB-1016 (AROCHLOR 1016)	28	0	.	.	.	.	.
PCB-1221 (AROCHLOR 1221)	28	0	.	.	.	.	.
PCB-1232 (AROCHLOR 1232)	28	0	.	.	.	.	.
PCB-1242 (AROCHLOR 1242)	28	0	.	.	.	.	.
PCB-1248 (AROCHLOR 1248)	28	0	.	.	.	.	.
PCB-1254 (AROCHLOR 1254)	28	0	.	.	.	.	.
PCB-1260 (AROCHLOR 1260)	28	0	.	.	.	.	.
PENTACHLOROPHENOL	28	0	.	.	.	.	.
PHENANTHRENE	28	2	0	2	2	2	2
PHENOL	28	0	.	.	.	.	.
PYRENE	28	0	.	.	.	.	.
TETRACHLOROETHYLENE	28	0	.	.	.	.	.
TOLUENE	28	23	1	1	2	4	24
TOXAPHENE	28	0	.	.	.	.	.
TRICHLOROETHYLENE	28	0	.	.	.	.	.
TRICHLOROFLUOROMETHANE	28	3	0	5	5	5	5
VINYL CHLORIDE	28	0	.	.	.	.	.
1,1-DICHLOROETHANE	29	0	.	.	.	.	.
1,1-DICHLOROETHYLENE	28	0	.	.	.	.	.
1,1,1-TRICHLOROETHANE	28	4	1	2	7	7	11
1,1,2-TRICHLOROETHANE	28	1	0	3	3	3	3
1,1,2,2-TETRACHLOROETHANE	28	0	.	.	.	.	.
1,2-DICHLOROBENZENE	28	0	.	.	.	.	.
1,2-DICHLOROETHANE	28	0	.	.	.	.	.
1,2-DICHLOROPROPANE	28	0	.	.	.	.	.
1,2-DIPHENYLHYDRAZINE	28	0	.	.	.	.	.
1,2-TRANS-DICHLOROETHYLENE	28	0	.	.	.	.	.
1,2,3-TRICHLOROBENZENE	28	0	.	.	.	.	.
1,3-DICHLOROBENZENE	28	0	.	.	.	.	.

Table 3-29 (Continued)

CONTROL AND METHOD BLANKS ANALYSES
PRIORITY POLLUTANT ORGANICS

COMPOUND	TOTAL NUMBER SAMPLES	TOTAL NUMBER DETECTS	NUMBER DETECTS >10 UG/L	STATISTICS FOR SAMPLES ANALYZED CONCENTRATIONS IN UG/L			
				MIN	MEDIAN	MEAN	MAX
1,3-DICHLOROPROPENE	28	0	.	.	.	.	.
1,4-DICHLOROBENZENE	28	0	.	.	.	.	.
2-CHLOROETHYL VINYL ETHER (MIXED)	28	0	.	.	.	.	.
2-CHLORONAPHTHALENE	28	0	.	.	.	.	.
2-CHLOROPHENOL	28	0	.	.	.	.	.
2-NITROPHENOL	28	0	.	.	.	.	.
2,3,7,8-TETRACHLORODIBENZO-P-DIOXIN	28	0	.	.	.	.	.
2,4-DICHLOROPHENOL	28	0	.	.	.	.	.
2,4-DIMETHYLPHENOL	28	0	.	.	.	.	.
2,4-DINITROPHENOL	28	0	.	.	.	.	.
2,4-DINITROTOLUENE	28	0	.	.	.	.	.
2,4,6-TRICHLOROPHENOL	28	0	.	.	.	.	.
2,6-DINITROTOLUENE	28	0	.	.	.	.	.
3,3-DICHLOROBENZIDINE	28	0	.	.	.	.	.
4-BROMOPHENYL PHENYL ETHER	28	0	.	.	.	.	.
4-CHLOROPHENYL PHENYL ETHER	28	0	.	.	.	.	.
4-NITROPHENOL	28	0	.	.	.	.	.
4,4-DDD	28	0	.	.	.	.	.
4,4-DDE	28	0	.	.	.	.	.
4,4-DDT	28	0	.	.	.	.	.
4,6-DINITRO-O-CRESOL	28	0	.	.	.	.	.

Pollutants Detected in a Small Number of Sources and Uniquely Related to Those Sources

Benzene was found only at plant A01 at concentrations above its detection limit (10 ug/l). The source of benzene at this facility is the dehydration unit where it is used as the dehydration solvent. (The maximum concentration of benzene from the dehydration column was 1,000 ug/l.) Since a variety of solvents are in use today, permit authorities should consider the establishment of a limitation for benzene if it is used at a particular facility.

Exclusion of the Remaining Priority Organic Pollutants

Data on treated effluent are available from three ethanol facilities (A03, E02, and E08). As Table 3-30 shows, the maximum concentrations of toluene, trichloroethylene, pentachlorophenol, and butyl benzyl phthalate are below their detection limit at every facility tested. These parameters are excluded as they are present in the treated effluent at levels too low to be reduced further by existing treatment technologies.

Data on untreated and treated effluent for phenol and chloroform are presented in Table 3-31. As this table shows, phenol was detected in the treated effluent at only one facility and this value is suspect since it is higher than the level detected in the untreated effluent. Chloroform was not detected in the treated effluent at plant E08; the presence of chloroform in the treated effluent at plant E02 is suspect as it was not detected in the influent stream to the treatment system. The concentrations of these pollutants in the treated effluent are too small to be quantified by approved analytical methods. Therefore, these pollutants are excluded also.

Exclusion of Priority Metals

Pollutants Present in Amounts Too Small to be Effectively Reduced by Known Technologies

The concentrations for priority pollutant metals found in the untreated effluent from ethanol facilities are presented in Table 3-32. All of these metals except copper, nickel, lead, and zinc are present in the untreated effluent at maximum concentrations so low that further reductions cannot be accurately quantified.

Pollutants Detected at a Small Number of Sources and Uniquely Related to Those Sources

The values for copper, nickel, and zinc present in the untreated effluent for each plant are presented in Table 3-33. As this

Table 3-30

CONCENTRATIONS OF TOXIC ORGANIC POLLUTANTS FOUND IN TREATED EFFLUENT FROM ETHANOL PLANTS (ug/l)

Pollutant	Total Number Samples	Total Number Detects	Max
benzene	11	3	1
chloroform	11	2	42
phenol	11	1	15
toluene	11	2	5
trichloroethylene	11	0	0

Table 3-31

BIOLOGICAL TREATABILITY OF CHLOROFORM AND PHENOL PRESENT IN ETHANOL PLANT WASTEWATERS

CHLOROFORM

	Untreated Effluent				Treated Effluent				
Plant Code	Total No. of Samples	Detects >10 ug/1	Mean (ug/1)	Max (ug/1)	Total No. of Samples	Detects >10 ug/1	Mean (ug/1)	Max (ug/1)	Percent Reduction
A03	4	0	ND	ND	4	0	ND	ND	--
E02	2	0	ND	ND	2	1	42*	42*	--
E08	6	0	5	8	6	0	ND	ND	100

PHENOL

	Untreated Effluent				Treated Effluent				
Plant Code	Total No. of Samples	Detects >10 ug/1	Mean (ug/1)	Max (ug/1)	Total No. of Samples	Detects >10 ug/1	Mean (ug/1)	Max (ug/1)	Percent Reduction
A03	1	1	7	7	1	1	15	15	--
E02	2	2	160	190	2	2	0	0	100
E08	6	5	45	82	6	0	0	0	100

---

*Results suspect since parameter was not detected in untreated effluent.

Table 3-32

PRIORITY METALS PRESENT IN UNTREATED ETHANOL PLANT EFFLUENT (ug/l)

Compound	Total Number Samples	Total Samples Above Detection Limit	Mean	Max
antimony (total)	23	6	4	10
arsenic (total)	23	9	3	8
beryllium (total)	23	5	2	8
cadmium (total)	17	12	6	17
chromium (total)	23	18	17	36
copper (total)	23	21	342	1210
cyanide (total)	23	1	9	11
lead (total)	17	10	54	189
mercury (total)	23	5	<1	1
nickel (total)	23	11	71	270
selenium (total)	23	9	5	43
silver (total)	23	5	1	3
thallium (total)	23	4	11	48
zinc (total)	23	22	164	590
asbestos (chrysotile) (>5 um)	3	0		
asbestos (fibrous) (>5 um)	3	0		
asbestos (chrysotile-fibers/ liter/10E5)	3	1	1	2
asbestos (total-fibers/liter/ 10E5)	3	3	243	690

Table 3-33

PRIORITY POLLUTANT METALS PRESENT IN UNTREATED EFFLUENT FROM ETHANOL PLANTS

Plant Code	Total No. of Samples	No. Samples > Detection Limit	Mean (ug/l)	Max (ug/l)
		Copper		
A01	3	1	19	48
A08	1	1	950	950
A06	3	3	158	227
A07	3	3	25	32
A10	2	2	559	1065
E02	2	2	71	71
E08	6	6	210	250
E09	3	3	762	1210
		Nickel		
A01	3	0	25*	25*
A03	1	1	4	4
A06	3	3	195	264
A07	3	3	46	50
A10	2	0	50*	50*
E02	2	2	261	270
E08	6	0	30*	30*
E09	3	2	6	8

*Detection Limit.

Table 3-33 (Continued)

PRIORITY POLLUTANT METALS PRESENT IN UNTREATED EFFLUENT FROM ETHANOL PLANTS

Zinc

Plant Code	Total No. of Samples	No. Samples > Detection Limit	Mean (ug/l)	Max (ug/l)
A01	3	2	357	590
A08	1	1	270	270
A06	3	3	138	164
A07	3	3	110	128
A10	2	2	114	121
E02	2	2	133	142
E08	6	6	64	119
E09	3	3	153	182

table shows, relatively high levels of copper were found in the treated effluent only at plants A03, A10, and E09. Likewise, only plants A06 and E02 had relatively high levels of nickel, and only plant A01 had a relatively high concentration of zinc. For the remaining facilities, the levels of these parameters are too low to be reduced further by known technologies. Permit authorities should consider the establishment of a limitation for copper, nickel, or zinc for a particular facility if these parameters are present at levels that can be treated.

Exclusion of the Remaining Priority Metals

The detection limit for lead varied from 5 ug/l to 200 ug/l for different analytical laboratories. When analytical values were reported such as <200 ug/l, a value of 100 ug/l was used to calculate the mean. The maximum and mean concentrations of lead in the untreated effluent were 189 and 54, respectively. This parameter was excluded as it was present at levels too low to quantify by approved analytical methods.

The Agency has determined that background levels for total asbestos fibers may be 10^5 to 10^7 fibers per liter of sample. Although the concentration values for the samples analyzed fall within this background range, further quantitative standards are to be promulgated in the near future. Therefore, consideration of this parameter will be deferred until such standards are set.

Exclusion of Conventional Parameters

The fecal coliforms present in the effluent from ethanol plants do not originate in the ethanol production process. The source of this parameter is the sanitary waste which is mixed with the ethanol plant effluent at some facilities. Currently fecal coliform levels are regulated under the NPDES permit program for those ethanol plants which treat their sanitary wastes rather than sending them to municipal treatment systems. Therefore, fecal coliform is excluded since it is uniquely related to a small number of sources within the industry.

The oil and grease parameter is a measure of the hydrocarbons, esters, oils, fats, waxes, and high-molecular weight fatty acids that are dissolved by extracting the aqueous sample with hexane or trichlorotrifluroethane (Freon). Oil and grease concentrations ranged from 3 mg/l to 1,560 mg/l. An analysis of the concentrations for individual plants reveals that the oil and grease contribution from an ethanol facility is process and plant specific. Therefore, permit authorities should consider the establishment of a limitation for oil and grease for facilities where this parameter is determined to be a concern.

Exclusion of Nonconventional Parameters

The analytical results for nonconventional metals in the untreated and treated effluent were presented in Tables 3-17 and 3-23, respectively. Maximum concentrations for six of these metals were found at levels above 1 ppm in both the treated and untreated effluent. These metals include aluminum, calcium, magnesium, sodium, iron, and phosphorus with maximum values of 1.2, 550, 38.5, 1,060, 5.4, and 63.9 mg/l, respectively, in the untreated effluent. There is no data available which suggests that these metals would be an environmental problem at the levels detected, therefore they are excluded.

Tables 3-18 and 3-24 presented the results for Appendix C compounds in the untreated and treated effluent. The only compound with a maximum concentration greater than 0.05 mg/l was diethyl ether with a maximum value of 0.8 mg/l in the untreated effluent. Diethyl ether is a common laboratory solvent and may be present as a contaminant at this low level. The Appendix C compounds are excluded as they are present at levels too low to be reduced further by known technologies.

The analytical results for the remaining nonconventional parameters analyzed in the treated and untreated effluent were presented in Tables 3-19 and 3-25, respectively. Very high values of total organic carbon (TOC), chemical oxygen demand (COD), total dissolved solids (TDS), total solids (TS), and temperature were measured for the untreated effluent. The data show that secondary biological treatment which reduces BOD_5 and TSS is also effective in reducing TOC, COD, TDS, and TS. Therefore, since BOD_5 and TSS have been selected for regulation; TOC, COD, TDS, and TS are excluded.

The concentration of total phenolics was present above the detection limit in the untreated effluents; however, its concentration was below the detection limit for the treated effluents for every facility tested. It is therefore excluded because it is present in the treated effluent at levels too low to be reduced further by existing treatment technologies.

In addition, the data show a reduction in the temperature of untreated effluent from an average value of 35°C (maximum of 44°C) to a value of 22°C (maximum of 30°C) for the treated effluent. These data do not indicate a need to regulate temperature for treated effluent from the average ethanol facility. However, permit authorities should consider the establishment of standards for temperature if this is determined to be a problem for a particular facility.

While the presence of the pollutants was insignificant in the facilities studied, they may be present in significant quantities at any specific facility and perhaps should be considered by permitting authorities if evidence indicates a concern.

3.6 AIR EMISSIONS

The Clean Air Act and its amendments created a comprehensive program to protect and enhance the Nation's air quality and a regulatory scheme for the control of air pollution. The cornerstone of the Act is the development of uniform national ambient air quality standards (NAAQS). Responsibility for limiting emissions to meet the ambient standards lies with the states. The Act required each State to develop state implementation plans (SIPs) which provide for implementing, maintaining, and enforcing the ambient standards.

The Act also requires the United States Environmental Protection Agency to establish three sets of nationally uniform emission limitations: new source performance standards (NSPS), hazardous pollution emission standards, and motor vehicle emission standards. NSPS requires the application of "best demonstrated technology" to new and modified stationary sources considering costs and health, energy and environmental impacts. The Act allows the States to require more stringent emission limitations than those developed for NSPS.

Part C of the Act, prevention of significant deterioration of air quality, provides EPA a means to regulate any pollutant from any major emitting facility which may adversely affect the public health and welfare. A major emitting facility for the ethanol- for-fuel industry would be any source which releases to the atmosphere or has the potential to release 227 metric tons/year (250 tons/year) or more of any pollutant.

In considering the air emissions associated with ethanol production, available emission data were used to (1) determine the magnitude of emissions and (2) assess the impact of State and Federal regulations on the ethanol-for-fuel industry.

A review of existing NSPS reveals that there are no regulations which specifically address the emissions from the ethanol-for-fuel industry. Proposed regulations that will apply to impact the industry include (1) NSPS for emissions from volatile organic liquid storage tanks that would have application to the industry's storage facilities and (2) NSPS for volatile organic compound (VOC) fugitive emissions in the synthetic organic chemical manufacturing industry that would specifically deal with fugitive VOC emissions from the industry.

VOC emissions from storage tanks were estimated and the cost of compliance to proposed regulations were calculated based on the work presented in the Background Information Document (BID) for VOC Emissions from Volatile Organic Liquid Storage Tanks. Similar tasks were performed for VOC fugitive emissions based on the BID for Fugitive Emissions from the Synthetic Organic Chemical Manufacturing Industry (SOCMI). It was found that there would be little or no cost to the industry, (or even a savings by preventing loss of product) from compliance to these proposed standards.

The assessment of the total projected emissions for ethanol plants and their source specific emissions indicates that sufficient regulatory activity exists to potentially control emissions without initiating additional regulatory efforts.

3.6.1 EMISSION SOURCES

Figure 3-2 illustrates the major sources of air emissions from a typical ethanol-for-fuel facility. These air emissions consist of particulate and volatile organic compounds (VOC), both point and fugitive sources. As Figure 3-2 shows, the sources for air emissions for a particular ethanol facility depend on the feedstock and by-product processing. Air emissions from ancillary processes, such as steam generation, are beyond the scope of this document and are not included.

Regardless of feedstock type or by-product processing, all ethanol-for-fuel facilities have air emissions from fermenter vents as well as condenser vents on distillation columns (e.g., the beer still and the dehydration column). Volatile organic compounds (VOC) such as ethanol, by-product fusel oils (primarily amyl alcohols), low molecular weight aldehydes (acetaldehyde, and formaldehyde), and dehydration agents (gasoline, benzene, or hexane) may be emitted from these sources. In addition, fugitive VOC emissions occur throughout the plant at valves, pumps, flanges, open-ended lines, and storage tanks.

By-product processing usually involves three steps: (1) centrifugation of the screened solids from the beer still, (2) concentration in evaporators, and (3) final drying in either direct-contact dryers or indirect steam heated dryers. VOC emissions occur from the condenser vents on evaporators. Indirect grain dryers are sources of particulates and VOC emissions. Direct-contact dryers often use boiler flue gases to dry the by-product grains; therefore, CO, SO_x, and NO_x occur in addition to particulate and VOC emissions.

Table 3-34 summarizes the major sources of air emissions for an ethanol-for-fuel facility which uses grain as a feedstock and practices by-product processing. The utilization of grain rather than sugar feedstocks for ethanol production results in the generation of additional particulate emissions. In the feedstock preparation step, fugitive particulate emissions occur during the unloading, loading, conveying, rough grinding, screening, cleaning (with shakers), and fine milling of the grain. If area ventilation is used to collect these emissions and then vented to the atmosphere, this becomes another point source emission.

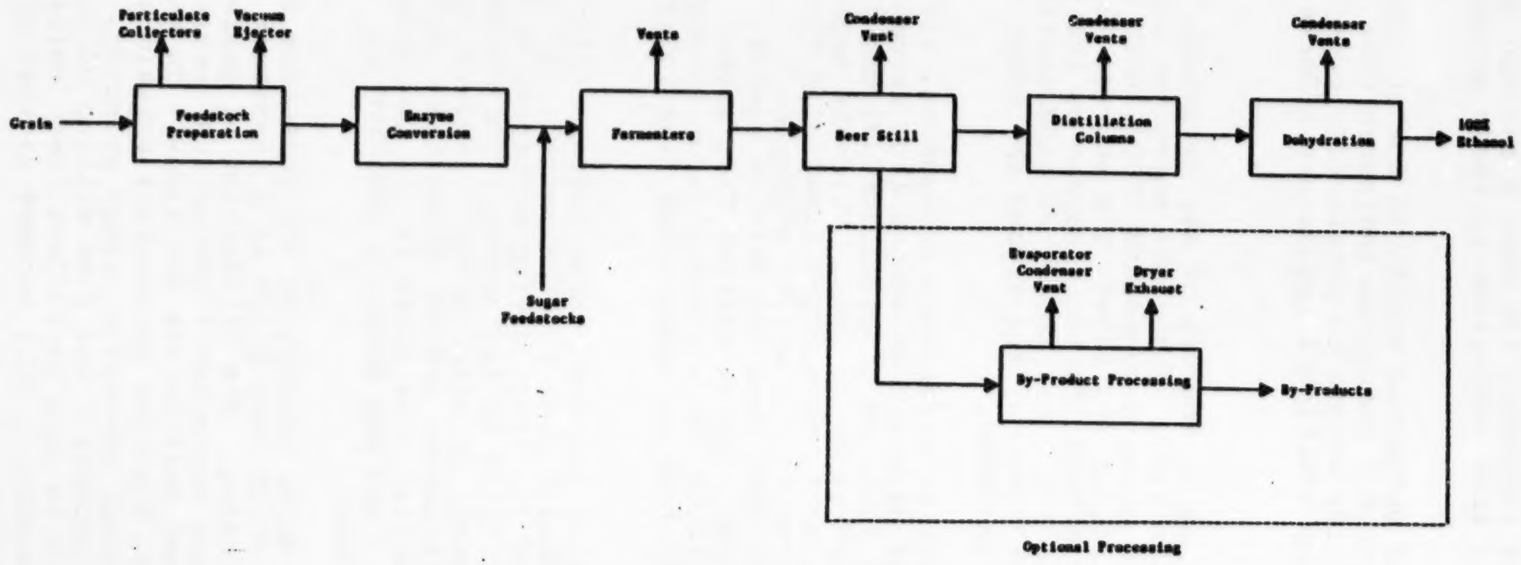
Grain
Particulate Collectors
Vacuum Ejector
Feedstock Preparation
Enzyme Conversion
Sugar Feedstocks
Vents
Fermenters
Condenser Vent
Beer Still
Condenser Vents
Distillation Columns
Condenser Vents
Dehydration
100% Ethanol
Evaporator Condenser Vent
Dryer Exhaust
By-Product Processing
By-Products
Optional Processing

Figure 3-2

MAJOR SOURCES OF AIR EMISSION FOR ETHANOL FACILITIES

Table 3-34

MAJOR SOURCES OF AIR EMISSIONS FROM AN ETHANOL-FOR-FUEL PLANT*

Grain Handling and Milling	Particulates
Fermenter Vents	Volatile Organic Compounds
Condenser Vents on Distillation Columns, Dehydration Columns, and Evaporators	Volatile Organic Compounds
Ejector Vent on Flash Cooler	Volatile Organic Compounds
Direct-Contact Dryer Exhaust	Particulates, CO, SO_x, NO_x, and Volatile Organic Compounds
Indirect-Contact Dryer Exhaust	Particulates, Volatile Organic Compounds
Valves, Pump Seals, Open-Ended Lines, Flanges, Storage Tanks	Fugitive Volatile Organic Compounds

*Based on a facility which uses grain and processes by-product grains.

Finally, grain feedstocks must be cooked to solubilize the starch portion in preparation for enzyme conversion of the starch to sugar. If the cooked grain is flash cooled, VOC emissions result from steam ejectors used to provide vacuum for the process.

3.6.2 EMISSION CHARACTERIZATION

To characterize emissions from ethanol-for-fuel plants, a sampling and analysis program was conducted at three facilities: two plants producing ethanol-for-fuel and one plant producing beverage alcohol. The test program was intended to give preliminary information on the type and magnitude of emissions from the industry.

A multimedia test program was conducted at plant A03 which included a screening of all the sources of air emissions. The sources tested and the analytical results are discussed below and presented in Tables 3-35, 3-36, and 3-37. Data are presented in standard conditions unless otherwise specified.

Plant A03 has a capacity of 61,000 m^3/year (16 x 10^6 gallons/year); approximately 11,000 m^3/year (3 x 10^6 gallons/year) is fuel grade ethanol. The plant feedstock consists of starch from a protein extraction unit as well as milled whole grain. The cooked mash is cooled in a flash cooler and then routed to the fermenter. The remaining process steps are similar to those shown in Figure 3-2; benzene is used as the dehydration agent.

VOC emissions were sampled at the fermenter vent, beer still condenser vent, solvent extractor condenser vent, fusel oil column condenser vent, dehydration column condenser vent, and the grain dryer cyclone outlet. The VOC emissions from the dryer would not be appreciably affected by the cyclone since it operates dry. The results (Table 3-35) indicate that the grain dryer had the greatest VOC emissions with 2.04 kg/hr (4.50 lb/hr). Total VOC emissions were 6.07 kg/hr (2.75 lbs/hr) or 0.41 lbs/ton on a production basis.

An OVA Century 108 hydrogen flame ionization detector was used to measure VOC emissions. The detector is sensitive to the specific type of compound being measured. Correction factors have been determined for several organic compounds that can be applied to determine the correct readings. However, a methodology has not been developed to adequately correct readings for a mixture of organic compounds. Therefore, for this study, the "worst" case was determined by applying the largest correction factor for those compounds believed to be present. In addition, the largest molecular compound present was used to determine the mass of the emissions. These methods, therefore, are quite conservative and actual emissions may be in the order of a magnitude less than those calculated.

Table 3-35

TOTAL HYDROCARBON (THC) AND BENZENE ANALYSES FOR PLANT A03

Stream/Parameter	Avg. Gas Velocity (m/s)	Avg. Gas Flow Rate (Dry m^3/hr)	Avg. Concentration (ppm)	Emissions[1] kg/hr (lbs/hr)
Fermenter Vent				
THC		174	95.7	0.07 (0.15)
Beer Still Condenser Vent				
THC	12,800	74	219	0.07 (0.15)
Solvent Extractor Condenser Vent				
THC	1,460	9.4	1,710	0.07 (0.15)
Rectifier Condenser Vent				
THC	<90	3.20	1,530	0.06 (0.13)
Fusel Oil Column Condenser Vent				
THC	1,140	4.6	973	0.02 (0.04)
Dehydration Column Condenser Vent				
THC	1,335	2.5	29,900	0.31 (0.68)
Benzene			17,000	0.03 (0.07)
Stripping Column Condenser Vent				
THC	1,370	2.5	55,400	0.58 (1.28)
THC			55,200	0.58 (1.28)
Benzene			52,900	0.10 (0.22)
Cyclone Vent on Dryer				
THC	55,600	63,390	7.7	2.04 (4.50)

---

[1] Corrected for OVA 108 sensitivity and based on major compound present (see Reference 1).

Table 3-36

PARTICULATE MATTER ANALYSIS AND SAMPLING DATA FOR PLANT A03/CYCLONE ON DIRECT-CONTACT BY-PRODUCT DRYER

	Particulate Sample #1	Particulate Sample #2
Average Flue Gas Velocity (m/s)	14.0	14.1
Average Flue Gas Temp. (°C)	98.9	88.3
Stack Pressure (kPa)	102	102
Flue Gas Composition		
H_2O	19.2	20.4
CO_2	5.0	5.1
O_2	6.5	0.5
CO	0	0.6
N_2	69.3	73.4
Flue Gas Total Flow (Actual m^3) (m^3/hour)	1,670 63,390	1,670 64,240
Flue Gas Grain Loading (grams/m^3)	0.04	0.02
Particulate Flow Rate (kg/hour)	2.8	1.6
Sample Percent Isokinetic	110.9	108.9

Table 3-37

SULFUR DIOXIDE AND NITROGEN OXIDE ANALYSIS FOR PLANT A03/ CYCLONE ON DIRECT-CONTACT BY-PRODUCT DRYER

Cyclone on Direct-Contact By-Product Dryer	Vol. Sampled (m^3)	Total Wt. of Species Collected (ug)	Gas Phase Concentration (ppm)	Gas Flow Rate (m^3/hr)	Emission (kg/hr)
SO_2 #1	0.86	<650[1]	<0.3	63,960	<0.050
SO_2 #2	0.76	<650[1]	<0.3	63,960	<0.050
NO_x #1	0.0013	67.5	26.1	63,960	1.4[2]
NO_x #2	0.0014	29.4	10.7	63,960	0.58[2]
NO_x #3	0.0013	21.9	8.3	63,960	0.58[2]
NO_x #4	0.0012	79.1	32.7	63,960	1.7[2]

---

[1] Detection limit.

[2] Lb/hour of NO_2.

The dehydration column and benzene stripping column were also tested for benzene which is used as a dehydration agent at this facility. The benzene emissions detected at the condenser vents on the stripping column and dehydration column were 0.10 kg/hr (0.22 lb/hr) and 0.03 kg/hr (0.07 lb/hr), respectively.

Particulate sampling was conducted on the cyclone which was used to remove particulate matter from the grain dryer exhaust. The inlet to the cyclone was inaccessible and therefore only the outlet was sampled. As Table 3-36 indicates, the emissions from the cyclone outlet averaged 2.2 kg/hr (4.7 lb/hr). Based on a conservative removal rate of 80 percent for the cyclone performance and estimated grain particle size distribution, the uncontrolled particulate emissions would be approximately 10.8 kg/hr (23.7 lb/hr). On a production weight basis emissions are 0.73 lbs/ton.

The flue gases from the gas-fired boiler were used in the by-product grain dryer, therefore, the cyclone outlet was also tested for SO_x and NO_x. Table 3-37 presents the results of this testing. The SO_x concentration (measured as SO_2) was below the detection limit. Nitrogen oxide concentrations were below 35 ppm which corresponds to an emissions less than 1.8 kg/hr (4.0 lb/hr).

After testing was completed at plant A03, two additional plants (A06 and E08) were selected for testing to provide further information on the magnitude of emissions from ethanol-for-fuel plants. These facilities were tested for fugitive emission sources as well as point sources. A beverage alcohol plant was included in the test effort since these plants were determined to be similar to the ethanol-for-fuel plants in volume and composition of air emissions. Data obtained at plant A03 were considered in determining which point sources were the major contributors. The final selection of sources and types of emissions for plants A06 and E06 are summarized in Table 3-38. A description of the sampling procedures used at each site is given in Appendix A.

Plant A06. Plant A06 is a new grassroots ethanol-for-fuel plant. The processes employed are similar to those shown in Figure 3-2. Benzene is also used in this plant as the dehydration agent. The plant has a production capacity of 11,360 m^3/yr (3 x 10^6 gallons/year).

Particulate sampling was conducted only on the by-product grain dryer which was equipped with a cyclone. The inlet to the cyclone was inaccessible and therefore not sampled. Particulate emissions from this source were 0.15 kg/hr (0.33 lb/hr) which is much less than the cyclone emissions for plant A03. The difference may be due to the difference in sampling methods. Assuming again an 80 percent efficient cyclone, the uncontrolled emissions would be approximately 0.75 kg/hr (1.65 lb/hr).

Table 3-38

1980 EPA SAMPLING PROGRAM/AIR EMISSIONS TESTING OF ETHANOL PLANTS

Plant Code	Stream Sampled	VOC	Particulates	Fugitive VOC Emissions
A06	Stream Ejector Vent	X		
	Fermenter Vent	X		
	By-Product Dryer Cyclone Outlet	X	X	
	Valves, Pump Seals, Flanges, Open-Ended Lines, Storage Tanks			X
E08	Corn Mill Vent - Baghouse Outlet		X	
	Centrifuge Vent	X		
	Conveyor Vents	X		
	Grain Dryer Cyclone Outlet	X	X	
	Valves, Pump Seals, Flanges, Open Ended Lines, Storage Tanks			X

VOC sampling was conducted on the cooker/cooler at the steam ejector discharge, the fermenter vent, and the cyclone exhaust on the by-product grain dryer. VOC emissions were greatest for the dryer, just as they were at plant A03. The average VOC emissions from the dryer were 9.6 kg/hr (21.1 lb/hr). This is much larger than the value for plant A03 which was 2.04 kg/hr. The differences could not be accounted for as sampling error but may be due to operational differences. On a production basis, the uncontrolled emissions are 0.66 g/kg (1.32 lb/ton) and 8.5 g/kg (16.9 lbs/ton), respectively, for particulate and VOC emissions.

Fugitive VOC emissions were measured from flanges, open ended lines, agitator seals, valves and pumps. Over 95 percent of these sources were screened using a portable Century System model OVA-108 portable hydrocarbon detector. The total VOC emissions were measured at 17.7 kg/day (39.0 lbs/day) as shown in Table 3-39. The VOC mass emissions were estimated from VOC emission factors developed by the Agency on petroleum refineries.

Plant E08. Plant E08 is a beverage alcohol plant with a capacity of 34,065 m^3/yr (9 x 10^6 gallons/yr). The processes employed are basically the same as those shown in Figure 3-2, although additional distillation columns are used to produce beverage grade ethanol.

Particulate sampling was performed on the corn mill vent and dryer. The corn mill is a hammer-type and is equipped with a baghouse. The inlet to the baghouse could not to be tested; therefore, only the outlet was sampled. As in plants A06 and A03, the dryer is equipped with a cyclone and again, the inlet was inaccessible.

Particulate results measured 0.55 kg/hr (1.22 lb/hr) and 0.02 kg/hr (0.05 lb/hr) of particulate from the dryer and corn mill, respectively. Assuming an efficiency of 99 percent, for the baghouse and 80 percent to the cyclone, uncontrolled emissions from the dryer and corn mill are approximately 2.76 kg/hr (6.1 lb/hr) and 2 kg/hr (4.4 lb/hr), respectively.

VOC sampling was performed on the centrifuge, conveyor vents, and dryer. VOC emissions were 0.04 and 0.07 kg/hr (0.02 and 0.03 lbs/hr), respectively, for the centrifuge and conveyor vents and 41.6 kg/hr (91.8 lb/hr) for the dryer. This is larger than the other plants measured and may be due to the presence of an oil aerosol in the exhaust stream during testing. On a production basis, uncontrolled emissions from the dryer are 0.81 g/kg (1.76 lb/ton) for particulate and 12.3 g/kg (24.6 lb/ton) for VOC emissions. VOC emissions would not be appreciably affected by the cyclone.

Table 3-39

FUGITIVE VOC EMISSION RESULTS FOR PLANT A06

Source	No. of Leaks <10,000 ppm	Emission* Factor kg/day	No. of Leaks >10,000 ppm	Emission* Factor	Emission kg/day (lbs/day)
Flanges	11	0.0072	.2	0.0072	0.09 (0.21)
Valves					
Gas	0	0.014	0	6.3	0
Light Liquid	5	0.041	3	2.0	6.21 (13.7)
Pumps	1	0.031	1	11.0	11.31 (24.9)
Open Ended Lines	2	0.055	0	0.055	0.11 (0.24)
Agitator Seals	0	0.31	0	11.0	0
Total Emissions					17.72 (39.07)

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*From "Assessment of Atmospheric Emissions from Petroleum Refining" Volume 3, Appendix B, pg. 48-55 and telecom with K. C. Hustvedt, Emission Standard and Engineering Division, U.S. EPA, Office of Air Quality Planning and Standards, Research Triangle Park, North Carolina, April 9, 1981.

Fugitive emissions were measured at flanges, valves, pumps, open ended lines, and agitator seals within the plant. Approximately 95 percent of these sources were tested. The total fugitive VOC emissions were determined as 6.7 kg/day (14.9 lbs/day) as shown in Table 3-40. Mass VOC emissions were estimated using VOC emission factors developed by the Agency on petroleum refineries.

3.6.3 NATIONAL EMISSIONS

The total particulate and VOC emissions were estimated for the current and projected ethanol-for-fuel industry using the data from plants A03, A06, and A08. The data from plant A03 include all major point sources of emissions from a typical ethanol-for-fuel plant and therefore are used to calculate national point source emissions. Fugitive VOC emissions were estimated from an average of fugitive emissions from plants A06 and E08: 12.2 kg/day (26.9 lbs/day) per plant, regardless of production capacity.

Table 3-41 presents the particulate and VOC emissions calculated for the current and 1985 projected ethanol-for-fuel industry. Based on a 1981 estimated production capacity of 6.2 x 10^5 cubic meters per year (1.6 x 10^8 gallons per year) from the industry, national particulate and VOC emissions are approximately 175 metric tons and 165 metric tons, respectively. If all the plants under construction and half of the plants proposed for construction are in operation by 1985, the projected production capacity from the resulting 71 plants would be 5.1 x 10^6 cubic meters per year (1.4 x 10^9 gallons per year). Projected particulate and VOC emission for 1985 are 1,500 metric tons and 1,130 metric tons, respectively.

3.6.4 EMISSION REGULATIONS

A review of existing NSPS reveals that there are no regulations which specifically address the emissions from the ethanol-for-fuel industry. Part C of the Act, prevention of significant deterioration of air quality, provides EPA a means to regulate any pollutant from any major emitting facility which may adversely affect the public health and welfare. A major emitting facility for the ethanol-for-fuel industry would be any source which releases to the atmosphere or has the potential to release 227 metric tons/year (250 tons/year) or more of any pollutant. Based on continuous operation this limit can be expressed as 28.6 kg/hr (63.1 lbs/hr). Reviewing the emission data gathered, only one test, at plant E08's dryer, resulted in emissions greater than 28.6 kg/hr and it is suspect. Otherwise, no data were available that demonstrate ethanol plants to be major emitting facilities.

Table 3-40

FUGITIVE VOC EMISSION RESULTS FOR PLANT E08

Source	No. of Leaks <10,000 ppm	Emission* Factor kg/day	No. of Leaks >10,000 ppm	Emission* Factor	Emission kg/day (lbs/day)
Flanges	2	0.0072	1	0.0072	0.02 (0.04)
Valves					
Gas	2	0.014	1	6.3	6.3 (14.0)
Light Liquid	0	0.041	0	2.0	0
Pumps	0	0.031	0	11.0	0
Open Ended Lines	2	0.055	0	0.055	0.11 (0.241)
Agitator Seals	1	0.31	0	11.0	0.31 (0.68)
Total Emissions					6.74 (14.9)

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*From "Assessment of Atmospheric Emissions from Petroleum Refining" Volume 3, Appendix B, pg. 48-55 and telecom with K. C. Hustvedt, Emission Standard and Engineering Division, U.S. EPA, Office of Air Quality Planning and Standards, Research Triangle Park, North Carolina, April 9, 1981.

Table 3-41

ESTIMATED PARTICULATE AND VOC EMISSIONS FROM THE CURRENT AND PROJECTED ETHANOL-FOR-FUEL INDUSTRY

	Current Industry (1981)	Projected* Industry (1985)
Total Number of Plants	15	71
Ethanol Capacity (M^3/Year)	0.62×10^6	5.1×10^6
Particulate Emissions (Metric Tons/Year)	175	1,500
VOC Emissions (Metric Tons/Year)	165	1,130
-Point Source	99	850
-Fugitive	66	280

*Includes all plants currently in operation and all plants currently under construction as well as 50 percent of the plants proposed for construction.

However, the ethanol-for-fuels industry should consider limiting the use of benzene as a dehydration agent in order to avoid emissions of benzene from the condenser vents of the dehydration columns and separators. Justifications for limiting the use of benzene are 1) an alternative dehydration agent that is less toxic, such as hexane or gasoline, is available and 2) benzene is listed by EPA as a hazardous air pollutant.

In addition, the Office of Air Quality Planning and Standards (OAQPS), United States Environmental Protection Agency (EPA) is presently developing background data for the support of regulations for volatile organic storage tanks and VOC fugitive emissions in the synthetic organic chemical manufacturing industry. NSPS for emissions from volatile organic liquid storage tanks would have application to the ethanol-for-fuel industry's storage facilities. NSPS for VOC fugitive emissions in the synthetic organic chemical manufacturing industry will specifically deal with fugitive VOC emissions from the industry.

Although impact of these proposed regulations on the ethanol-for-fuel industry cannot be quantified until the regulations are promulgated, the impact may be estimated.* The background information document (BID) for VOC Emissions from Volatile Organic Liquid Storage Tanks (EPA, a, 1980) evaluated several alternative methods to reduce or control VOC emissions. Alternative III, contact internal floating roof with primary seals only, was the second most cost effective alternative evaluated and had the lowest impact on product price, actually enabling product price to decrease as a result of applying the alternative. Cost impacts were projected assuming this alternative will be chosen to promulgate NSPS.

Emissions from ethanol storage facilities are not available, however; the BID for storage tanks developed equations to estimate VOC emissions. These equations were used to estimate both baseline and controlled emissions (EPA, a, 1980). The baseline emissions were estimated at 0.48 Mg/year of VOC for an average plant of 7.1 x 10^4 m^3/year. The controlled emissions were estimated at 0.16 Mg/year, a reduction in VOC emissions of 67 percent. The annualized costs of the control technique per plant is estimated at $86. The annualized costs for the entire industry in 1985 would be only $7,000 (20).

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*Impacts of these "proposed" air pollution regulations were estimated in 1980. At the time this document was published in 1986, the status of these regulations was as follows: A) Standards regulating volatile organic liquid storage vessels were proposed on July 23, 1984 (49FR 29698). The BID was updated and is listed in Reference 38. (B) Standards regulating VOC fugitive emissions were promulgated on October 18, 1983 (48FR 48328). The BID was updated and is listed in Reference 39. For both regulations, the BID alternatives used in the ethanol-for-fuels cost analyses are not significantly different from the alternatives found in the updated BIDs. Thus, updated cost analyses were not performed just prior to publication of this document.

The BID for VOC Fugitive Emissions in Synthetic Organic Chemicals Manufacturing Industry (21) evaluated several alternatives to reduce VOC fugitive emissions. Alternative II was the most cost effective alternative evaluated and also produced the lowest impact on product price, actually allowing a decrease in product price. This alternative would require leak detection and repair methods be implemented. Leak detection is accomplished by use of a portable VOC detection instrument. Air near the potential leak area is sampled and analyzed. If VOC emissions are greater than 10,000 ppm, then equipment repair would be required. Cost impacts were estimated assuming this alternative is chosen as a basis for promulgating NSPS. The estimated VOC fugitive emissions for the industry in 1985 are 280 Mg/year. The total annualized costs without recovery credits for the industry to control these emissions are estimated to be $80,000; if recovery credits are included, a net annual savings of $22,000 would result (20).

There would be no or very little cost impact of these proposed standards on the ethanol-for-fuel industry. Furthermore, these proposed standards could actually result in savings to the industry by preventing the loss of product.

3.7 SOLID WASTES

The Resource Conservation and Recovery Act (RCRA) was passed in 1976 to provide for more uniform solid waste control. The purpose of RCRA is three-fold: (1) regulation of hazardous waste management; (2) provide technical and financial assistance for the safe disposal of wastes; and (3) provide technical and financial assistance for developing facilities and plans to recover energy and other resources from discarded materials.

RCRA was designed with the following principal features: regulation of certain wastes, defined or characterized as hazardous, are to be the responsibility of the federal government; and regulation of nonhazardous wastes is to be a state responsibility, in conformance with federal guidelines. However, under RCRA Section 3006, states are authorized and encouraged by EPA to develop and carry out their own hazardous waste programs in lieu of a federally administered program. Authorization for state run programs must be granted by EPA and is being initially administered through an "interim status" program. "Final authorization" will be possible after Section 3004, Part 264 requirements are promulgated.

To determine if industry-specific regulations are needed and their subsequent impact, the prevailing factor is whether the waste is considered hazardous or nonhazardous under the Resource Conservation and Recovery Act. If one or more of the solid waste streams generated by ethanol-for-fuel facilities are considered to be hazardous, the Administrator has the authority to "list" such streams. When this occurs the generators, transporters, and disposers of these wastes must comply with all appropriate Subtitle C regulations of the Resource Conservation and Recovery Act (RCRA 3000 Series). Wastes which are not hazardous are subject to Subtitle D regulations (RCRA 4000 Series).

3.7.1 SOLID WASTE SOURCES

Data on solid waste streams from ethanol facilities were obtained during a sampling and analysis program. Details on site selection, waste stream selection, parameters analyzed, and test methods are presented in this section.

It was determined that none of the solid waste streams from ethanol-for-fuel plants exhibit the characteristics of ignitability, corrosivity, reactivity, or EP toxicity. Thus the solid waste streams would not be considered hazardous under RCRA. Since the ethanol production solid wastes are nonhazardous, no industry-specific regulations are required. Existing federal guidelines which pertain to nonhazardous wastes are sufficient at this time.

The two major solid waste streams at an ethanol-for-fuel plant are the by-product stream and the biosludge stream that results from secondary treatment of process wastewater. Since the by-products have a significant market value they are most often recovered and sold. Ultimate disposal of the biosludge is therefore the only factor which will effect total plant treatment costs.

In order to present a conservative or "worst" case cost analysis, the cost of gravity thickening, aerobic digestion, centrifugation, and contract hauling were estimated since these methods are capital intensive. The production of biosludge is a direct result of wastewater treatment and therefore, the costs associated with biosludge treatment and disposal are included in Section 6 under the cost of direct discharge wastewater treatment options. In addition, the economic impact and cost/benefit aspects of biosludge treatment and disposal or management are discussed in the wastewater treatment section of this document.

In order to evaluate the impact of solid waste regulations on the ethanol-for-fuel industry, an assessment was made of the solid waste streams generated by the ethanol production process, air emission controls, and wastewater treatment. Solid wastes from ancillary processes such as steam generation are beyond the scope of this document.

Figure 3-3 presents a generic diagram of an ethanol production process. One solid waste stream from an ethanol-for-fuel facility is grain dust collected from particulate controls (e.g., cyclones) associated with grain milling and by-product drying. In most cases, particulates collected in grain milling are sent to the cooker and particulates from by-product drying are recycled to the dryer. Therefore, these wastes are not considered further in this analysis. Other solid waste streams are stillage from the beer still, if not processed into by-products, and the processed by-products, if they cannot be sold.

Figure 3-4 presents a diagram of the solid waste streams from process wastewater treatment. The solid waste streams are the treated wastewater if it is land applied and biosludge from secondary wastewater treatment which may be land applied, landfilled or hauled away by a contractor.

All of the waste streams identified above are actually potential waste streams. It is possible, although not probable, that an ethanol-for-fuel facility might produce no solid wastes. This would occur if the grain dust were recycled, the beer stillage was either sold wet or processed into by-products which were then sold, and the process wastewater was indirectly discharged to a publicly owned treatment works (POTW). However, an actual facility will most likely have at least one solid waste stream.

3.7.2 EVALUATION OF SOLID WASTE STREAMS

In 1980, the EPA conducted a test program to characterize the solid wastes and potential solid wastes from ethanol-for-fuel facilities. At the inception of this test program, there were five ethanol plants producing ethanol-for-fuel; all five plants were considered for solid waste sampling. To increase the data base, several beverage alcohol plants were also considered for testing, as this industry was determined from an engineering standpoint to be analogous to the ethanol-for-fuel industry in terms of the characteristics and volume of solid wastes generated. Three ethanol-for-fuel and two beverage alcohol facilities were chosen for sampling in order to include processes which use different feedstocks and produce various by-products.

A presampling visit was made to each candidate ethanol facility to assess the operation of the plant and the accessibility of the solid waste streams. The final selection of the sample points and sample type based on the site visits is summarized in Table 3-42 and discussed further below. A description of the techniques used to collect the solid samples is provided in Appendix A.

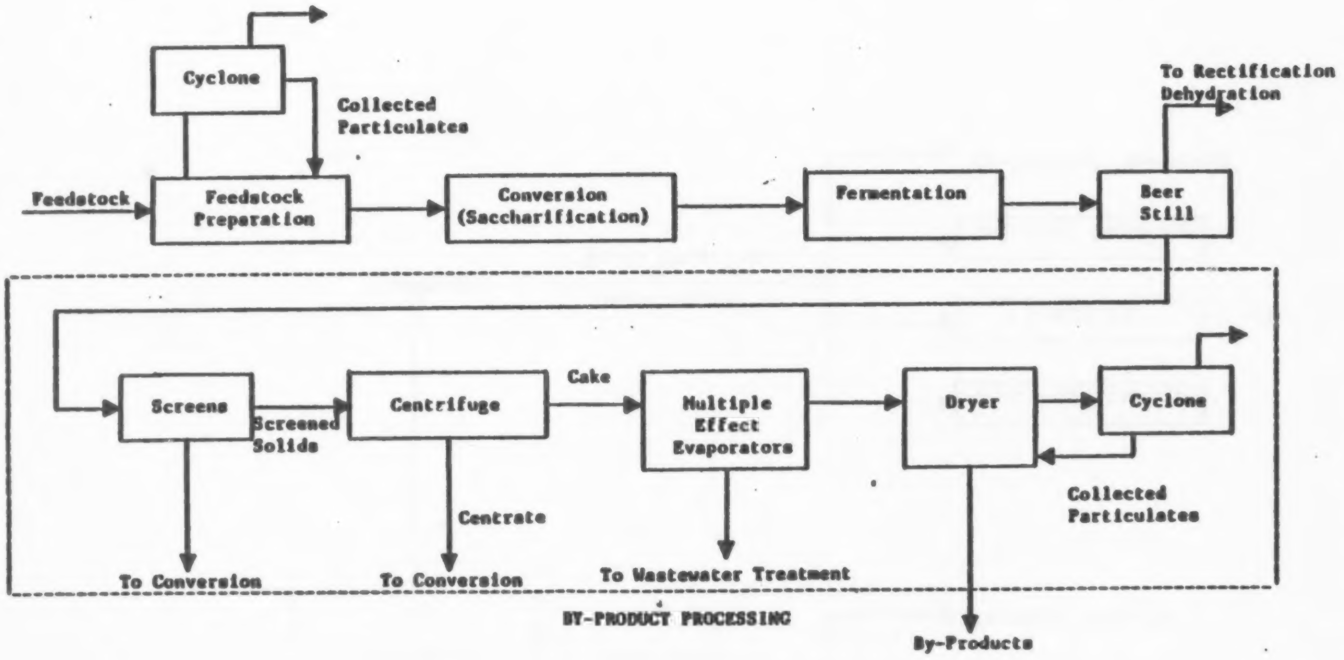
Cyclone
Collected Particulates
Feedstock
Feedstock Preparation
Conversion (Saccharification)
Fermentation
Beer Still
To Rectification Dehydration
Screens
Screened Solids
Centrifuge
Cake
Multiple Effect Evaporators
Dryer
Cyclone
Collected Particulates
Centrate
To Conversion
To Conversion
To Wastewater Treatment
BY-PRODUCT PROCESSING
By-Products

Figure 3-3
SOLID WASTE STREAMS FROM ETHANOL PRODUCTION

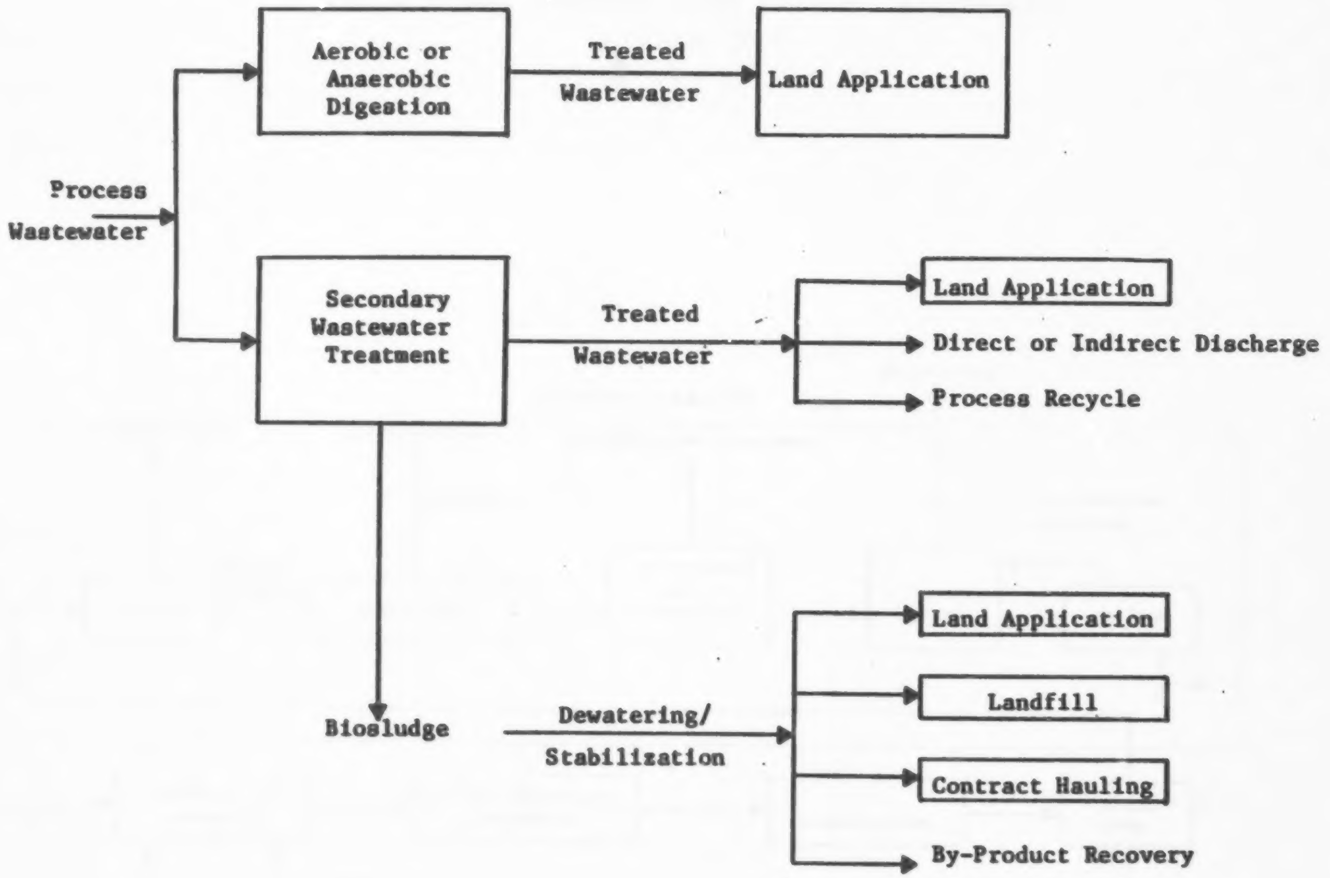
Process
Wastewater
Aerobic or Anaerobic Digestion
Treated Wastewater
Land Application
Secondary Wastewater Treatment
Treated Wastewater
Land Application
Direct or Indirect Discherge
Process Recycle
Biosludge
Dewatering/ Stabilization
Land Application
Landfill
Contract Hauling
By-Product Recovery

Figure 3-4
SOLID WASTE STREAMS FROM PROCESS WASTEWATER TREATMENT

Plant A01. This ethanol plant routes all solid wastes associated with ethanol production to a centralized feed house where wastes from other processes are handled. The solid waste from the ethanol facility cannot be sampled separately; thus, no solid waste sampling was proposed for this facility.

Plant A03. In 1979, this plant was sampled for air, water, and solid wastes in a program conducted by EPA/IERL-Ci. Solid waste samples of by-product grains and biological sludge were collected for metal analyses (which had not been addressed in the IERL-Ci study).

Plant A06. No solid wastes were sampled from this facility as its wastes were similar to those collected from plants A03 and E09.

Plant A07. The solid wastes from this plant are routed to a lignin plant and were not selected for sampling.

Plant A10. Solid waste streams chosen included by-product condensed cheese whey solubles (CWS) and core samples of land that had been subjected to spray irrigation with treated effluent.

Plant E02. The types of solid samples that were proposed for collection at this facility were the by-products produced and the wasted biosludge from the bottom of the sludge thickener. The by-product samples included the beer still bottom stillage and the condensed molasses solubles.

Plant E08. Feedstock grain and the by-product DDGs were sampled from bulk storage piles. Also, a sample of sludge was collected from the bottom of the wastewater treatment aerated lagoon.

Plant E09. There are two solid waste streams from this plant: feedstock grain and by-product grains. Both of these streams were chosen for sampling and analysis.

In addition to the streams listed in Table 3-42, samples of the feedstocks were collected to determine if the raw materials used were the source of toxic pollutants or contaminants which might be detected in the waste streams.

3.7.3 RCRA RELATED ANALYTICAL PARAMETERS AND TEST METHODS

According to the criteria outlined in RCRA, a solid waste can be defined as hazardous if it exhibits any of the characteristics identified as corrosivity, ignitability, reactivity, and extraction procedure (EP) toxicity. At the inception of the solid waste test program (April 1980), a comparison was made of the solid waste from ethanol plants and the proposed methods of determining corrosivity, ignitability, and reactivity. Based on this comparison, it was ascertained that ethanol-for-fuel solid

Table 3-42

FACILITIES AND SOLID WASTE STREAMS TESTED

Facility	Solid Waste Stream Tested
A03	Biosludge Distillers Dried Grains
A10	Condensed Whey Solubles Core Samples
E02	Beer Still Bottom Stillage Condensed Molasses Solubles Biosludge
E08	Biosludge Distillers Dried Grains
E09	Distillers Dried Grains

wastes would not be considered hazardous using these criteria. Therefore, EP toxicity was the only hazardous property evaluated further in this study.

To determine if a solid waste exhibits the characteristic of EP toxicity, RCRA requires that the wastes be extracted with (1) acetic acid and (2) distilled water and that these extracts (or leachate samples) be analyzed for compounds listed as toxic contaminants. Table 3-43 presents a list of the toxic pollutants which must be analyzed to determine EP-toxicity, as well as their detection limits and maximum allowable concentrations.

According to the 19 May 1980 issue of the Federal Register (Volume 45, Number 98, page 33122) (22), a waste can be considered to exhibit the characteristic of EP toxicity if the extract from the waste contains any of the contaminants listed in Table 3-43 at a concentration equal to or greater than the respective value given in that table.

The results of the test program for RCRA related solid wastes are presented in Table 3-44. Of the 14 compounds listed in Table 3-43, only two were found at levels above their detection limits: barium and chromium. Barium levels ranged from 25 to 1,300 ppb and chromium varied from 1 to 35 ppb. These levels are well below those designated as rendering a waste hazardous. Therefore, the solid wastes from ethanol-for-fuel facilities examined in this document are classified as nonhazardous according to EP toxicity criteria.

In addition to leachate analysis, the solid waste samples were also analyzed to determine if the solid wastes, rather than contamination, were the source of any toxic pollutant found in the leachate analyses. The results from the solid digestion analyses are presented in Appendix D. Since no toxic pollutants were detected above the maximum allowable concentrations in the leachate analyses, no further analysis of the solid digestion data is required at this time.

Other analytical parameters which were evaluated are presented in Table 3-45. The analytical methods used for all the parameters identified are discussed in Appendix B. The results for the leachate analysis and the solid digestion analyses are presented in Appendix D. The Agency has determined that none of these other pollutants were present at levels which are considered to be hazardous at this time.

All of the RCRA related parameters (Table 3-43) as well as the other parameters (Table 3-45) were tested for on samples of the ethanol plant feedstocks. The results of the leachate analysis and the solid digestion analyses are presented in Appendix D. None of the pollutants were detected at levels which are considered to be hazardous at this time.

Table 3-43

POLLUTANT PARAMETERS ANALYZED TO DETERMINE RCRA EP-TOXICITY

Toxic Metals	Detection Limit (ppb)	Maximum Allowable Concentration (ppb)[1]
Arsenic	2	5,000
Barium	1	100,000
Cadmium	42	1,000
Chromium	5	5,000
Lead	2	5,000
Mercury	0.2	200
Selenium	2	1,000
Silver	10	5,000
Pesticides		
2-4 D	0.8	10,000
2,4,5 TP Silvex	0.3	1,000
BHC (Lindane)-Gamma	0.2	400
Endrin	2	20
Methoxychlor	2	10,000
Toxaphene	100	500

[1] Source: 19 May 1980 Federal Register, Volume 45, Number 98, p. 33122 (22).

Table 3-44

RCRA RELATED SOLID WASTE ANALYSIS SUMMARY

POLLUTANT PARAMETER: BARIUM

	Acetic Acid Leach			Distilled Water Leach		
Stream	Total No. Samples	Number Samples > Detection Limit	Range (ppb)	Total No. Samples	Number Samples > Detection Limit	Range (ppb)
Beer Still Bottom Stillage	2	2	370 - 420	2	2	610 - 660
Distillers Dried Grains	3	3	220 - 1,300	3	3	750 - 1,000
Condensed Whey Solubles	1	1	270	1	1	25
Condensed Molasses Solubles	1	1	440	1	1	730
Biosludge	5	5	84 - 510	5	5	79 - 600
Core Samples	5	5	94 - 420	5	5	130 - 190

POLLUTANT PARAMETER: CHROMIUM

	Acetic Acid Leach			Distilled Water Leach		
Stream	Total No. Samples	Number Samples > Detection Limit	Range (ppb)	Total No. Samples	Number Samples > Detection Limit	Range (ppb)
Beer Still Bottom Stillage	2	0	-	2	1	16
Distillers Dried Grains	3	1	5	3	2	6 - 8
Condensed Whey Solubles	1	0	-	1	0	-
Condensed Molasses Solubles	1	0	-	1	1	35
Biosludge	5	1	1	5	1	1
Core Samples	5	1	24	5	0	-

Table 3-45

ANALYTICAL PARAMETERS ANALYZED FOR SOLID WASTE TESTING

Metals	Detection Limit (ppb)	Metals	Detection Limit (ppb)
Aluminum	50	Nickel	15
Beryllium	2	Phosphorus	180
Bismuth	250	Platinum	600
Boron	45	Potassium	40
Calcium	40	Silicon	16
Cobalt	30	Sodium	11
Copper	5	Strontium	2
Gold	48	Tellurium	520
Indium	280	Tin	600
Iron	8	Titanium	25
Lithium	2	Uranium	320
Magnesium	500	Vanadium	15
Manganese	6	Wolfram	90
Molybdenum	10	Yttrium	9
		Zinc	15

Anions*	Detection Limit (ppb)
Chloride	
Nitrate	600
Sulfate	
Total Organic Carbon	1,000

*Distilled water leachate samples were not analyzed for anions.

SECTION 4

WASTEWATER TREATMENT AND CONTROL TECHNOLOGY

4.1 BACKGROUND

Applicable technologies effective in reducing or eliminating pollutants present in wastewater from ethanol-for-fuel plants include in-plant source control methods for wastewater reduction, such as plant management practices and production process modifications; preliminary, primary, secondary, and tertiary wastewater treatment technologies; disinfection and sludge handling. The pollutant parameters of concern are BOD_5, TSS, and pH as discussed in Section 3.5.

The quantity and characteristics of untreated effluent generated by beverage alcohol facilities are not significantly different from that generated by ethanol-for-fuel facilities. This is strong evidence that the control and treatment technologies used by beverage alcohol plants are not only applicable to ethanol-for-fuel facilities, but should also result in similar performance and reduction of pollutant parameters. Hence, treatability data from both industries are presented in this section.

A survey of the ethanol-for-fuel industry in 1981, which includes data on 15 facilities, reveals that 12 facilities (80 percent) were indirect dischargers (or facilities discharging into publicly owned treatment works). This high percentage is attributed to the fact that most existing ethanol-for-fuel facilities are small; two-thirds of existing ethanol-for-fuel plants have capacities less than three million gallons of ethanol per year. Combining these data with the available data from 16 beverage alcohol plants, the indirect dischargers then comprise about 50 percent of the industry. All of the beverage alcohol plants considered have capacities larger than three million gallons of ethanol per year. In addition to size, plant location also influences whether a particular facility is a direct or indirect discharger. In 1981 there were three large facilities, with capacities greater than 15 million gallons per year, located in urban areas which were also indirect dischargers.

In regard to level of technology practiced, all beverage alcohol and ethanol-for-fuel plants which were direct dischargers use secondary biological treatment systems. Many of these treatment systems also incorporated some form of preliminary treatment (e.g., neutralization, bar screening) and/or primary treatment (e.g., coarse screens, primary sedimentation). In addition, 60 percent of the indirect dischargers from the ethanol-for-fuel industry (44 percent of the indirect dischargers from both ethanol industries) use secondary biological treatment before discharging their effluent to a municipal treatment plant.

The most common methods of secondary treatment in use at ethanol plants were aerated lagoons, stabilization or oxidation ponds, activated sludge systems, trickling filters, and rotating biological contactors (in that order). Data were available on the treatability of BOD_5 and TSS from 12 ethanol plant secondary treatment systems; these data are summarized in Table 4-1. As this table shows, BOD_5 reduction varies from 87.6 to 98.7 percent and TSS reduction varies from 25.2 to 96.3 percent. The low TSS reduction associated with plant E18 is due to a problem with algal growth in the stabilization pond.

No tertiary treatment was in use at ethanol-for-fuel plants; however, one beverage alcohol plant had a polishing pond and another used an air flotation unit. No data was available which quantifies treatability of BOD_5 or TSS from these tertiary methods of treatment when used on ethanol plant wastewaters.

Finally, all plants which combine their domestic wastes with process wastes (25 percent of the plants surveyed) use chlorination for disinfection. The effectiveness of disinfection by chlorination for bacteria (e.g., fecal coliform) is nearly 100 percent if proper dosage rates and sufficient contact times are used.

4.2 IN-PLANT SOURCE CONTROL FOR WASTEWATER REDUCTION

The generation of wastewater from facilities that produce ethanol via fermentation can vary from as much as 5.5 gallons of wastewater per gallon of ethanol for plant A06 to 33.7 gallons of wastewater per gallon of ethanol for plant E09 (see Table 6-3). The wide range in these ratios is a result of the former plant's efforts to minimize wastewater generation by improved plant management practices and production process changes. These practices can only be effective in conjunction with increased management awareness of the importance of in-plant control.

4.2.1 PLANT MANAGEMENT PRACTICES

The primary plant management practices for wastewater reduction include proper spill disposal, washwater control, and water conservation.

Table 4-1

BOD_5 AND TSS REDUCTION ACHIEVED BY ETHANOL PLANT WASTEWATER TREATMENT SYSTEMS

Plant Code	Wastewater Treatment System	Percent BOD_5 Reduction	Percent TSS Reduction
A03	Activated Sludge	98.7	95.0
E02	Aerated Lagoon with Stabilization Pond	87.6	55.6
E05	Aerated Lagoon with Stabilization Pond	96.5	77.5
E06	Activated Sludge with Stabilization Pond	91.9	82.9
E07	Aerated Lagoon with Rotating Biological Contactor	93.3	73.8
E08	Aerated Lagoon with Rotating Biological Contactor	97.0	73.0
E12	Trickling Filter with Stabilization Pond	96.4	92.9
E13	Aerated Lagoon with Stabilization Pond	94.5	82.5
E15	Aerated Lagoon with Stabilization Pond	98.3	84.4
E17	Aerated Lagoon with Trickling Filter	97.2	76.1
E18	Aerated Lagoon with Stabilization Pond	98.2	25.2
E21	Activated Sludge	98.6	96.3
	Average of Treatment Systems' Performance	95.7	80.7*

*Average does not include value for plant E18.

Spill Disposal

Spills from ethanol-for-fuel facilities may result from tank overflows, the loss of heating or cooling in the distillation columns, pumping equipment malfunctions, or operator error. The containment and disposal of these spills can be facilitated by the use of a process centralized sump or a spill lagoon.

Plant A01 has a centrally located sump in its distillation building. The spill disposal system has been designed such that, depending on the liquid in the sump, the spill can be recycled to the distillation columns for ethanol recovery or pumped to the wastewater treatment facility.

Spill lagoons, such as the ones maintained by plant E02 and E15, function in a similar fashion, but they are larger and not designed to recycle the spilled liquid back to the ethanol production process. The spill lagoon liquid is gradually added to the wastewater treatment system to prevent upsets in the secondary biological treatment operation which may result from a fluctuating wastewater strength.

Washwater Control

The quantity of washwater generated at an ethanol-for-fuel facility is less than that produced by beverage alcohol plants because of the lower purity requirements of the former industry. However, certain washes, such as those for the fermenters, are still required to avoid bacterial contamination. Common in-plant controls which may be employed to reduce waste generation include:

1. Install central cleanup systems such as clean-in-place (CIP) units (valved or triggered hoses). These systems generate a controlled-pressure supply of hot or warm water containing a detergent and reportedly clean better with less water (ESE, 1974). Plants E09 and E10 use CIP units to clean the fermenters and feedstock delivery trucks, respectively.

2. Eliminate practices of unnecessary washwater use. Many plants operate water valves wide open, regardless of actual need. The installation of ball valves in water lines after globe valves reduces water usage since the ball valve functions as a volume adjustment and the globe valve as an on/off controller.

Water Conservation

Techniques that are available for wastewater reduction by water conservation include:

1. Install automatic shutoff valves. Water hoses equipped with these valves can save up to 60 gallons per minute when employees forget to shut off hoses (14).

2. Install low-volume, high-pressure systems on all water sprays which cannot be eliminated.

3. Recirculate water for reuse in feedstock preparation (e.g., washing, mashing) or, if applicable, extractive distillation.

4. Parallel product purity with water purity by introducing the fresh water in the latter stages of production and then reusing it in earlier stages of the process. This technique reduces the input of fresh water.

5. Recycle of noncontact waters from mash cooling and the distillation column condenser, and any noncontact streams of suitable quality for other in-plant uses.

4.2.2 BEST MANAGEMENT PRACTICES

Plant management practices can be required in NPDES permits as Best Management Practices (BMPs). BMPs are broad and may include processes, procedures, human actions, or construction requirements. Pursuant to Sections 304 and 402 of the Clean Water Act, BMPs may be incorporated into permit conditions supplemental to numerical effluent llimits.

BMPs in NPDES Permits

BMPs are placed in permits in two basic ways: BMP plans and site- or pollution-specific BMPs. Site-specific BMPs may be imposed as specific conditions of the BMP plan or as independent provisions of the permit. BMP plans are usually kept on-site and made available to the permitting authority on request. The normal compliance schedule is to require preparation of the plan within six months, and implementation within twelve months, of permit issuance. Nine specific requirements have been identified as a basis for developing BMP plans in the NPDES program. Site-specific or pollutant-specific BMPs are left to the discretion of the permit writer and are highly dependent upon a careful review of the circumstances at a particular facility. The minimum requirements of a BMP plan are presented below.

Minimum Requirements of a BMP Plan

1. General Requirements

    - Name and location of facility
    - Statement of BMP policy and objective
    - Review by plant manager

2. Specific Requirements

- BMP committee
- Risk identification and asssessment
- Reporting of BMP incidents
- Materials compatibility
- Good housekeeping
- Preventive maintenance
- Inspections and records
- Security
- Employee training

BMP Committee

The BMP committee is that group of individuals within the plant organization which is responsible for developing the BMP plan and assisting the plant management in its implementation, maintenance, and updating. Thus, the committee's functions are similar to those of a plant fire prevention or safety committee. Plant management, not the committee, has overall responsibility and accountability for the quality of the BMP plan.

The scope of activities and responsibilities of the BMP committee should include all aspects of the facility's BMP plan, such as identification of toxic and hazardous materials addressed in the plan; identification of potential spill sources; BMP inspections and records procedures, review of environmental incidents to determine and implement necessary changes to the BMP plan; coordination of incident notification, response, and clean-up procedures; establishment of BMP training programs for plant personnel; and aiding interdepartmental coordination in carrying out the BMP plan.

Risk Identification and Assessment

The areas of the plant subject to BMP requirements should be identified by the BMP committee, plant engineering group, environmental engineer, or others in the plant. Each such area should be examined for the potential risks of discharges to receiving waters of toxic pollutants or hazardous substances from ancillary sources. Any existing physical means (dikes, diversion ditches, etc.) of controlling such discharges also should be identified.

A hazardous substances and toxic chemicals inventory (materials inventory) should be developed as part of the risk identification and assessment. The details of the materials inventory should be proportionate to the quantity of toxic pollutants and hazardous substances on site and their potential for reaching the receiving waters.

Reporting of BMP Incidents

A BMP incident reporting system is used to keep records of incidents such as spills, leaks, runoff, and other improper discharges for the purpose of minimizing recurrence, expediting mitigation or cleanup activities, and complying with legal requirements. Reporting procedures defined by the BMP committee should include: notification of a discharge to appropriate plant personnel to begin immediate action; formal written reports for review and evaluation by management of the BMP incident and revisions to the BMP plan; and notification, as required by law, of government and environmental agencies.

Materials Compatibility

Materials compatibility includes the consideration of: compatibility of the chemicals being stored with the container materials; compatibility of different chemicals upon mixing in a container; and compatibility of the container with its environment. The BMP plan should provide procedures to address these three aspects in the design and operation of the equipment used for the storage or transfer of toxic and hazardous materials.

Incompatible materials can cause equipment failure resulting from currosion, fire, or explosion. Equipment failure can be prevented by ensuring that the hazardous substances or toxic pollutants are compatible with the container contents and the surrounding environment.

Good Housekeeping

Good housekeeping is the maintenance of a clean, orderly work environment and contributes to the overall facility pollution control effort. Periodic training of employees in housekeeping techniques for those plant areas where the potential exists for BMP incidents reduces the possibility of mishandling of chemicals or equipment.

Examples of good housekeeping include neat and orderly storaage of bags, drums, and piles of chemicals; prompt cleanup of spilled liquids to prevent significant runoff to surface waters; sweeping, vacuuming, or other cleanup of accumulations of dry chemicals as necessary to prevent them from reaching receiving waters; and provision for storage of containers or drums to keep them from protruding into open walkways or pathways.

Preventive Maintenance

An effective preventive maintenance (PM) program is important to prevent environmental incidents. A PM program involves inspection and testing of plant equipment and systems to uncover conditions that could cause breakdowns or failures, with resultant significant discharges of chemicals to surface waters. The program should prevent breakdowns and failures by adjustment, repair, or replacement of items.

A PM program should include a suitable records system for scheduling tests and inspections, recording test results, and facilitating corrective action. Most plants have PM programs that provide a degree of environmental protection. A BMP plan should not require the development of a redundant PM program. Instead, the plan should reinforce the objective to have qualified plant personnel (e.g., BMP committee, maintenance foreman, or environmental engineer) evaluate the existing plant PM program and recommend to management those changes, if any, needed to address BMP requirements.

A good PM program includes identification of equipment or systems to which the PM program should apply; periodic inspections or tests of identified equipment and systems; appropriate adjustment, repair, or replacement of items; and maintenance of complete PM records on the applicable equipment and systems.

Inspections and Records

An inspection and records system detects and documents actual or potential BMP incidents. The BMP plan should include written inspection procedures and optimum intervals between inspections. Records to show the completion date and results of each inspection should be signed by the appropriate supervisor and maintained for a period of three years. A tracking or follow-up procedure should be instituted to ensure that adequate response and corrective action have been taken. The record keeping portion of this system can be combined with the existing spill reporting system in the plant.

The inspection and records system should include those equipment and plant areas having the potential for significant discharges. To determine the inspection frequency and inspection procedures, experienced personnel should evaluate the causes of previous incidents, the likelihood of future incidents, and assess the probable risks for incident occurrence or recurrence. Consideration should be given to the nature of chemicals handled, materisls of construction, and site-specific factors including age, inspection techniques, and cost effectiveness of BMPs employed.

Security

A security system prevents accidental or intentional entry to a plant which might result in vandalism, theft, sabotage, or other improper or illegal use of plant facilities that possibly could cause a BMP incident. Most plants have security systems to prevent unauthorized entry.

The BMP plan should describe those portions of the existing security system and any improvements that are necessary to ensure toxic chemicals are not discharged to receiving waters in significant quantities as a result of unauthorized entry. Documentation of the security system may require separate filing from the BMP plan to prevent unauthorized individuals from gaining access to sensitive or confidential information.

Employee Training

Employee training programs should install in personnel, at all levels of responsibility, a complete understanding of the BMP plan. Training should address the processes and materials on the plant site, the safety hazards, the practices for preventing discharges, and the procedures for responding properly and rapidly to toxic and hazardous materials incidents.

Meetings should be conducted at least annually to assure adequate understanding of the objectives of the BMP plan and the individual responsiblities of each employee. Typically, these could be a part of routine employee meetings for safety or fire protection. Such meetings should highlight previous spill events or failures, malfunctioning equipment, and new or modified BMPs.

Training sessions should review the BMP plan and associated procedures. Just as fire drills are used to improve an employee's reaction to a fire emergency, spill or environmental incident drills may serve to improve the employee's reactions to BMP-related incidents. Plants are encouraged to conduct spill drills on a quarterly or semi-annual basis. Spill or incident drills serve to evaluate the employee's knowledge of BMP-related procedures and are a fundamental part of employee training.

Site-Specific or Pollutant-Specific BMPs

Site-specific and pollutant-specific BMPs are those designed to address conditions peculiar to a facility or pollutant. The need for specific BMPs at a facility often will be discovered in conjunction with other permit-related activities, such as compliance inspections. Poor housekeeping or a history of spills, for example, indicate a need for site-specific BMPs to supplement the quantitative effluent limits on specific pollutants in the permit. These "situation-specific" BMPs may be conventional, such as secondary containment around a storage tank, or innovative, such as siting containers so that a spill caused by a careless forklift operator will not flow into the river. Other examples of site-specific BMPs are contained in recent NPDES permits.

4.2.3 PRODUCTION PROCESS MODIFICATIONS

A wide range of values for the quantity of wastewater generated per gallon of ethanol produced is not only linked to plant management practices, but also to equipment selection. The following process changes can be implemented to reduce wastewater generation:

1. The addition of instrumentation for the automatic control of evaporator operation at optimum levels of liquid/solid separation. Evaporator performance below the optimum operating conditions can increase entrainment by stillage flashing upon entering the evaporator or foaming. Entrained solids significantly increase the BOD and TSS of the evaporator condensate sent to wastewater treatment.

2. The replacement of barometric condenser systems used in mash cookers, mash coolers, and evaporators with surface (noncontact) condensers. The cooling water added to the condensate increases the hydraulic load requirements of the wastewater treatment system. The barometric condensate can amount to as much as 28 percent of the total BOD load (14).

3. The use of reboilers rather than live steam for heating the distillation columns can reduce wastewaters from the column bottoms by 20 to 30 percent (14).

4. The removal of the purifying columns from beverage plants planning to convert to ethanol-for-fuel production indirectly reduces wastewater generated by lowering steam and cooling requirements.

4.3 PRELIMINARY TREATMENT TECHNOLOGIES

In order to allow downstream operations to perform effectively, the influent to the wastewater treatment system is often subjected to preliminary treatment such as bar screening, comminuting, equalization, and neutralization. The use of bar screens and communitors protects pumps and other equipment downstream from damage by large solids. An equalization basin provides the necessary flow rate control, while a neutralization system provides pH control. Biological treatment tolerates only a small pH range; thus, control of the influent stream is required to prevent pH shock.

4.3.1 BAR SCREENING

Screening, as a method for removing large suspended particles, is commonly used in wastewater treatment plants. The ethanol-for-fuel plants using screening are A01, A03, and A07. Bar screens or bar racks are considered to be a preliminary treatment option and can be used to protect plant equipment against large solids which can cause physical damage. A bar screen is made of vertical steel bars spaced at equal intervals across a channel through which the wastewater flows. Openings between the bars range from 50 to 150 mm (two to six inches), thus preventing large, heavy objects from entering the treatment plant and damaging pumps or other downstream equipment (23). The screen is automatically cleaned by a traveling rake. Bar screens are used ahead of raw wastewater pumps, flow meters, grit chambers, and primary sedimentation tanks.

4.3.2 COMMINUTORS

Comminutors are cutting devices that cut influent waste materials to six to nineteen mm in length (0.25 to 0.75 inch) without removing material from the flow (23). They serve the same basic function as bar screens by reducing the size of solids entering the treatment plant. These devices are currently being used by several beverage alcohol plants.

4.3.3 GRIT REMOVAL

Wastewater grit materials are characterized as nonbiodegradable, having a subsiding velocity substantially greater than that of organic biodegradable solids, and they are generally discrete rather than flocculent in nature. Materials falling into these categories are particles of sand, gravel, and other minute pieces of mineral matter. Grit is removed from a wastewater system to protect moving mechanical equipment from abrasion and abnormal wear; reduce conduit clogging; and prevent loading of treatment works with inert matter that may interfere with the operation (e.g., siltation of anaerobic digestors or aeration tanks). Grit removal devices are currently classified as either horizontal flow or aerated.

The quantities of grit removed via mechanical cleaning in a horizontal flow device or in the hoppers of an aeration device can vary greatly. Values separated range from 3.1 m^3 per million liters to 225 m^3 per million liters for municipal treatment systems. Aeration tank grit removal devices can achieve, with proper adjustment, greater than 99 percent grit removal.

The choice of grit removal method is usually determined from factors such as head loss requirements, space requirements, types of equipment used elsewhere in the plant, and the costs of each of the three alternatives. Aerated grit removal offers the advantages of minimal head loss through the grit chamber, low biodegradable solids removal, and simultaneous grease removal by surface skimming. In addition, the wastewater may undergo some BOD_5 reduction because of the contact with air. Aerated grit chambers can also be used for chemical addition prior to primary settling (23).

The grit that is stored in hoppers is usually disposed of by truck hauling to a landfill for large installations. For individual wastewater treatment systems encountered at ethanol plants, the amount of this material which would be collected is relatively small compared to other solid waste streams. Only one plant, E08, was reported to use grit removal as part of a primary treatment scenario.

4.3.4 EQUALIZATION

A common problem in ethanol-for-fuel wastewater treatment plants is rapidly changing influent wastewater flow rate and BOD_5 concentration. A decrease in flow rate can reduce settler overflow rates while an increase in flow rate can decrease solids removal efficiency. Changes in influent wastewater concentration can result in process overloadings and ultimately bring about decreases in effluent quality. Equalization acts to control fluctuation in both flow rate and concentration.

An equalization basin is simply a basin to which the influent wastewater is pumped at varying flow rates; wastewater is simultaneously pumped out of the equalization basin at a constant (or near constant) flow rate and fed to the downstream treatment units. Wastewater in the equalization basin is mixed, either by mechanical mixing or by air sparging. The mixing results in less variation in the BOD_5 concentration of the wastewater pumped from the equalization basin and prevents solids from settling and accumulating on the bottom of the basin.

Typical schematic flow diagrams of equalization basins are shown in Figure 4-1. As illustrated by the figure, there are basically two different equalization flow schemes: in-line equalization and side-line equalization (24). In-line equalization has been found to provide the greatest flow rate and concentration damping, as well as minimizing the effects of toxic shock loads and providing some pH stabilization. In-line equalization is practiced at ethanol-for-fuel plant A01 as well as beverage alcohol plants E04 and E21. Thus, in-line equalization is recommended when biological treatment is being used (24).

4.3.5 NEUTRALIZATION

In a study of the beverage alcohol industry, Environmental Science Engineering found that the pH of the combined process effluent may vary from a value of four to eleven over a 24-hour period (13). Also, the data presented in Section 3 of this document reveal a pH fluctuation of three to 13 for raw wastewaters from this industry. Generally, Publicly Owned ment option and can be used to protect plant equipment against large solids which can cause physical damage. A bar screen is made of vertical steel bars spaced at equal intervals across a channel through which the wastewater flows. Openings between the bars range from 50 to 150 mm (two to six inches), thus preventing large, heavy objects from entering the treatment plant and damaging pumps or other downstream equipment (23). The screen is automatically cleaned by a traveling rake. Bar screens are used ahead of raw wastewater pumps, flow meters, grit chambers, and primary sedimentation tanks.

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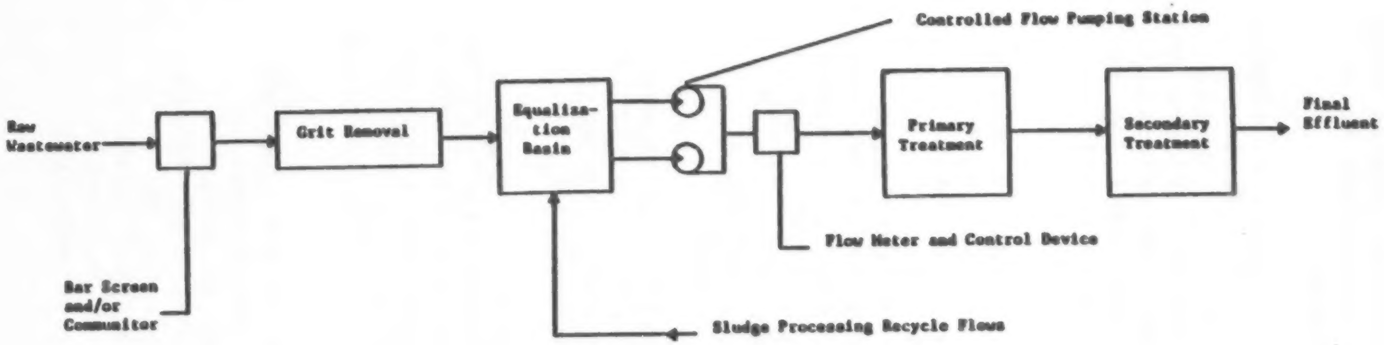
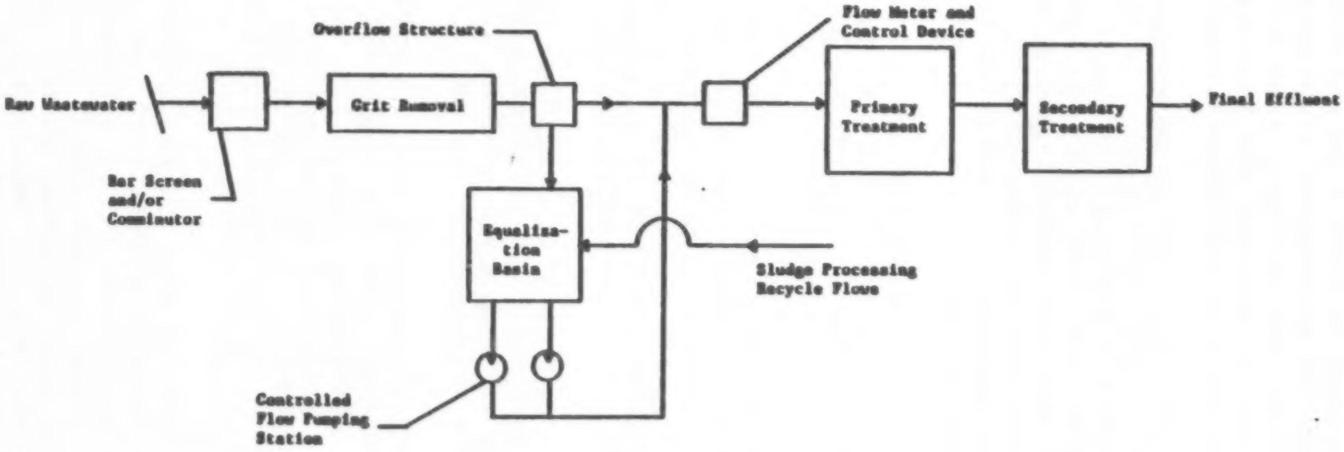

Raw Wastewater
Bar Screen and/or Communitor
Grit Removal
Equalization Basin
Controlled Flow Pumping Station
Flow Meter and Control Device
Sludge Processing Recycle Flows
Primary Treatment
Secondary Treatment
Final Effluent

IN-LINE EQUALIZATION


Raw Wastewater
Bar Screen and/or Comminutor
Grit Removal
Overflow Structure
Equalization Basin
Controlled Flow Pumping Station
Sludge Processing Recycle Flows
Flow Meter and Control Device
Primary Treatment
Secondary Treatment
Final Effluent

SIDE-LINE EQUALIZATION

Figure 4-1
SCHEMATIC FLOW DIAGRAMS OF EQUALIZATION FACILITIES

Source: (27)

Treatment Works (POTWs) require any wastewater being discharged into their system to have a pH between 6.0 and 9.0. The optimum pH for biological wastewater treatment is in the range of 6.5 to 8.5 (25). Thus, the effluent from ethanol-for-fuel plants will require pH control whether the wastewater is discharged to a POTW or to an on-site biological treatment system.

The conventional name for pH adjustment in wastewater treatment applications is neutralization. In the ethanol-for-fuel and beverage alcohol industries, a common practice is to combine alkaline washwaters with acidic process wastewater. Plants A01, A03, and A07 use this method of neutralization. Occasionally, further neutralization consisting of acid or base addition is required when sufficient quantities of alkaline or acidic wastewater are not available.

A variety of alkaline substances can be used. Lime is usually the least expensive alkali source, although both sodium hydroxide (NaOH) and sodium carbonate (Na_2CO_3) have been used. Pebble quicklime, which is simply high calcium quicklime in pebble form, is easier to handle and creates fewer dust problems than other forms of lime (24). Quicklime is fed into a lime slaking tank, where the solid quicklime (CaO) is reacted with water to form a calcium hydrate ($Ca(OH)_2$) slurry. The lime slurry is then pumped into a holding tank, where it is mixed to maintain the lime in suspension and is fed by a metering pump into the neutralization reaction tank.

In general, either sulfuric acid or hydrochloric acid is used as an acid for neutralization. Both acids are handled as liquids from delivery to application. The acid is stored on-site in a storage tank and pumped to the neutralization reaction tank.

A neutralization reaction tank is used to provide for proper mixing and contact time for the complete neutralization of the wastewater. Wastewater enters the tank, mixes with the acid or base reagent, and exits after adequate reaction time has been provided. Depending on the pH of the raw influent wastewater, the tank may be constructed of a variety of corrosion resistant materials (e.g., stainless steel or concrete).

An integral part of any neutralization system is the control system which usually consists of one or more continuous pH probes which are connected to a microprocessor or other controller. Based on the signal received from the pH probes, either base or acid is added to the wastewater. If pH fluctuations are not too rapid, a manually operated control system may suffice. However, systems which use automatic control have been found to be more reliable than manually controlled systems.

4.4 PRIMARY TREATMENT TECHNOLOGIES

The removal of suspended solids by physical means (e.g., settling or flotation) is usually considered to be primary treatment technology. Currently, the most widely used primary treatment operations in the ethanol industry are coarse screening and sedimentation. The reduction of solids in primary treatment reduces the oxygen requirements of downstream biological units and reduces the solids loading to the secondary sedimentation tank.

Untreated effluent from ethanol-for-fuel facilities had a median total suspended solids (TSS) concentration of 380 miligrams per liter (mg/l) with a maximum concentration of 2,680 mg/l. Typical raw domestic sewage has TSS concentrations in the range of 100 to 350 mg/l (26). Thus, wastewaters from ethanol-for-fuel facilities may have concentrations of suspended solids many times higher than domestic sewage. If discharged to a POTW, these solids could result in overloading of the POTW's primary sedimentation tanks depending on the ratio of ethanol-for-fuel wastewater flow to domestic sewage flow. Such high suspended solids concentrations can bring about problems in secondary treatment systems. If the solids are biodegradable, the secondary treatment system (e.g., activated sludge system, aerated lagoon) might be overloaded.

4.4.1 COARSE SCREENING

As a method of primary treatment, coarse screening may be used to prepare wastewater high in suspended solids for either discharge to a POTW or discharge to further on-site treatment such as an activated sludge system or an aerated lagoon. The suspended solids present in wastewaters from ethanol-for-fuel facilities are, for the most part, readily biodegradable. Removal of suspended solids in a preliminary treatment step may offer a significant cost savings for plants with complete on-site wastewater treatment systems. This cost savings is possible because removal of biodegradable solids in primary treatment can result in a reduction in the aeration basin volume and air supply capacity of the secondary treatment system. Coarse screens are used in the beverage alcohol industry and are used in ethanol-for-fuel plant A03.

Coarse woven-wire media screens are used after bar screens to remove material prior to introducing wastewater to biological filters or gravity sand filters. Screens of this type were developed in the mid-1960's for use in dewatering pulp slurries in the pulp and paper industry (27). They have also been applied for the treatment of raw domestic sewage where TSS removals in the range of five to twenty-five percent have been achieved (27).

A rotating wedge wire screen has also been developed that has the advantage of being self-cleaning and has been found useful where grease binding problems were encountered with stationary wedge wire screens. Rotating screens are also reported to require less maintenance, they have a lower head loss, and they require less space than stationary screens. They also produce a sludge with a higher solids concentration. However, rotating screens have a higher capital cost (27).

4.4.2 SEDIMENTATION/COAGULATION

Sedimentation is the removal of solid particles from a suspension by gravitational settling. Sedimentation basins are often referred to as clarifiers. Plants A07, E11, and E12 have primary sedimentation basins for suspended solids reduction.

The settling characteristics of suspended particles are a function of the nature of the particles, their concentration, and conditions in the settling device. There are no data available concerning removal efficiency for ethanol plant wastewater; however, the literature suggests that a properly designed and operated primary sedimentation tank can remove 50 to 70 percent of the suspended solids and 25 to 40 percent of the BOD from domestic sewage (26).

In addition to providing for effective removal of suspended solids from its effluent, a clarifier must have an adequate sludge removal capacity and provide sufficient reduction in sludge volume to facilitate sludge handling and processing. The clarifier may also be equipped with a skimming device to collect scum that floats to the surface.

In the event that the particulate impurities in wastewater are too small for gravitational settling alone to be an effective removal process, chemical agents can be added to induce an aggregation of these small particles into readily settleable agglomerates which can be removed by some other method (e.g., sedimentation, air flotation, or filtration). This process is referred to as coagulation.

There are many types of chemical agents (coagulants or coagulant aids) available, including lime, aluminum and iron salts, synthetic organic polymers, and activated silica. The type and dosage of coagulants cannot be determined without some experimentation; the performance of a coagulant is most often evaluated using a jar test. The removal efficiency in coagulation depends upon the particles in the wastewater to be treated, other chemical characteristics of the solution, and the coagulant aid which is used.

4.5 SECONDARY TREATMENT TECHNOLOGIES

The term secondary treatment refers to the removal of dissolved organics that cannot be removed in primary screening or settling processes. Dissolved organics consist of many different chemical compounds and are usually measured in terms of the generalized parameter biochemical oxygen demand (BOD). In addition to BOD removal, some total suspended solids (TSS) is also removed.

Based on ethanol-for-fuel industry questionnaire responses and data gathered by ESE (14) on the beverage alcohol industry, the following distribution of secondary wastewater treatment methods were found to be applied at existing plants:

Type of Secondary Treatment	% Plants Using Technology to Treat at Least Part of their Wastewater
Aerated Lagoon	65
Stabilization Ponds	30
Activated Sludge	20
Trickling Filter	15
Rotating Biological Contactors	10

NOTE: Some ethanol plants employ more than one of the above treatment technologies; thus, the total does not sum to 100 percent (sample population of 24 plants).

Four ethanol-for-fuel plants have wastewater treatment systems. Plants A06 and A07 use aerated lagoons for treatment, plant A03 uses an activated sludge system and discharges directly to a river, while plant A01 pretreats with an activated sludge system then discharges to a POTW. In addition, trickling filters and rotating biological contactors are also applicable to the ethanol-for-fuel industry. ESE determined in its study of the beverage alcohol industry that ethanol plant wastewaters are typically low in the nutrients nitrogen and phosphorus, which are essential for proper growth of the activated sludge microorganisms (14). The data in Section 3 indicate that nutrient addition is also necessary for the proper operation ofsecondary treatment technologies when treating wastewaters from ethanol-for-fuel facilities.

4.5.1 NUTRIENT ADDITION

In order to maintain optimum efficiency in biological systems, minimum quantities of nitrogen and phosphorus are required for cell synthesis. Without a proper nutritional balance, soluble BOD_5 reduction and liquid-solid separations are impaired.

A summary of typical influent wastewater characteristics for grain distilleries based on the data presented in Section 3 is shown in Table 4-2. As this table indicates, the wastewaters are deficient in both nitrogen and phosphorus. To maintain proper cell growth, nitrogen and phosphorus must be added to the wastewater. Nitrogen is usually provided by the addition of ammonia; phosphorus is provided by the addition of phosphoric acid. Both of these chemicals can be stored on-site in steel storage tanks and pumped into the aeration basin at an appropriate rate.

4.5.2 AERATED LAGOONS

Aerated lagoons are basins in which aeration is accomplished by either mechanical aerators (usually by fixed or floating surface aerators) or by diffused air piping systems. The BOD removal rate is waste specific and temperature sensitive and must be determined by laboratory or pilot unit testing. Therefore, for a specific waste and temperature, the BOD removal is only a function of detention time (assuming a completely mixed aerobic system). A single cell aerated lagoon can obtain good removal of soluble BOD, but the effluent will contain suspended solids in the same concentrations as the mixed liquor. A greatly improved effluent can usually be achieved by following the aerated lagoon with a second unmixed polishing lagoon where suspended solids are allowed to settle.

There are two common designs in use: the completely mixed basin in which all solids are kept in suspension (aerobic lagoons) and the partially mixed aerated lagoon in which the heavier solids settle to the bottom of the basin (facultative lagoon). In the former design, stabilization of organics is entirely aerobic. In the latter, the settled solids undergo anaerobic biological decomposition while suspended and dissolved organics undergo aerobic biological decomposition.

Aerobic lagoons have a shorter retention time than facultative lagoons to achieve the equivalent soluble BOD removal. However, a greater mixing requirement and therefore more power input is necessary for the aerated lagoon. Several aerators are needed to ensure complete mixing in the aerobic lagoon. These aerators provide oxygen and keep the solids in suspension. Diffused aeration (used at plant A07) generates coarse bubbles and is recommended where severe winter conditions can render surface aerators ineffective. The effluent from an aerobic lagoon is high in BOD_5 caused by unsettled microbial solids. In order to remove these suspended solids, some designers of aerobic lagoons include baffled sections which provide for solids settling before discharge.

Table 4-2

TYPICAL INFLUENT WASTEWATER CHARACTERISTICS AT GRAIN DISTILLERIES

Wastewater Parameter	Untreated Wastewater Grain Distilleries
BOD_5 (mg/l)	1,500
Total Nitrogen (mg/l)	21
Total Phosphorus (mg/l)	2
BOD:N:P*	100:1.4:0.13

*Recommended value of the BOD:N:P ratio is 100:5:1 (28).

In facultative lagoons, aeration is only required to disperse oxygen. The solids are allowed to settle to the bottom of the lagoon where anaerobic biological degradation of the organic matter takes place. Surface aerators are commonly used; in climates with severe winters diffused aeration may be required.

Figure 4-2 shows the wastewater treatment system in use at Plant E13 which contains an aerated lagoon. Also, part of the system is a stabilization pond which is used to reduce solids and a chlorinator for disinfection (sanitary wastes are mixed with ethanol plant wastes). This plant has a BOD_5 reduction of 94.5 percent and a TSS reduction of 82.5 percent (14).

4.5.3 STABILIZATION PONDS

A stabilization pond is a relatively shallow body of water contained in an earthen basin which utilizes no induced aeration. These ponds are designed to treat wastewater in the following manner: (1) settling of solids; (2) equalization and control of wastewater flow; and (3) stabilization of organic matter by aerobic and facultative microorganisms, and also by algae.

Stabilization ponds are usually classified by the biological activity occurring as aerobic, anaerobic, or aerobic-anaerobic. Aerobic-anaerobic stabilization ponds are the second most widely used biological treatment option by ethanol facilities and are only found as the final stage in biological treatment following other methods of secondary treatment. Large ponds allow plants to store wastewaters during periods of high flow in the receiving body of water or for irrigation purposes in the summer. Stabilization ponds are common in rural areas where land is available and relatively inexpensive.

Stabilization ponds are usually one to two meters deep and have hydraulic retention times of one to six months. In these relatively deep ponds, the wastewater near the bottom may be void of dissolved oxygen. Therefore, settled solids may be decomposed by aerobic, anaerobic, or facultative organisms, depending upon lagoon conditions. It is essential to maintain aerobic conditions in the top layer of the pond since aerobic microorganisms effect the most complete removal of organic matter.

Disadvantages of stabilization ponds include their reduced effectiveness during winter months which may require supplemental aeration, increased design capacity, and possible provisions for no discharge during long periods of time (winter months). Also, stabilization ponds require a relatively large amount of land. Algal growth may lead to high suspended solids in the effluent. Odor may also become a problem if the pond becomes anaerobic (e.g., if covered with ice during winter).

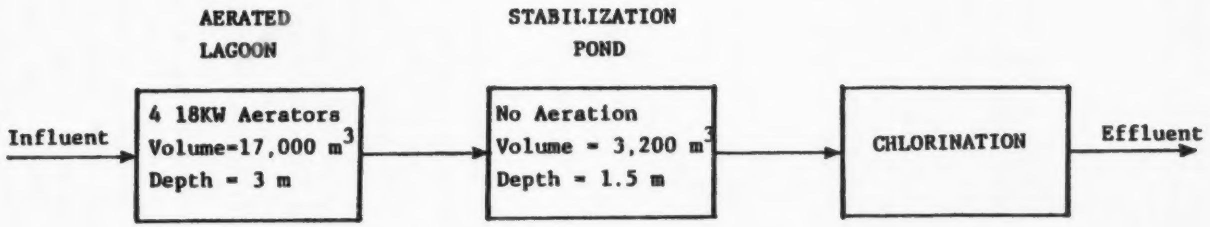

AERATED LAGOON
STABILIZATION POND
Influent
4 18KW Aerators
Volume=17,000 m3
Depth = 3 m
No Aeration
Volume = 3,200 m3
Depth = 1.5 m
CHLORINATION
Effluent

Figure 4-2
PLANT E13
AERATED LAGOON WASTEWATER TREATMENT SYSTEM

No data is available concerning the effectiveness of stabilization ponds alone on the effluent from ethanol plants. In other industries, stabilization ponds can achieve BOD_5 removals up to 95 percent; however, the pond effluent contains a high concentration of bacteria and algae that may exert a higher BOD_5 than the original waste (26). There are several methods available for removing algal cells from lagoon effluents, including coarse-medium filtration (developed primarily for this purpose) and algal harvesters.

4.5.4 ACTIVATED SLUDGE

The activated sludge system is one of the most frequently applied methods of biological wastewater treatment. The process has shown itself to be capable of high BOD removal efficiency (85 to 99 percent) and can be adapted to almost any type of biological waste treatment problem. This flexibility has led to numerous modifications of the "conventional" activated sludge process. The most common type of activated sludge process in use today in the beverage alcohol and ethanol-for-fuel industry is extended aeration.

Extended aeration differs from a conventional activated sludge process in that it is operated with relatively long hydraulic residence times and a high sludge age. Oxygen requirements may be twice that of a conventional activated sludge unit. The extended aeration process is used in the ethanol-for-fuel and beverage alcohol industries due to its ability to handle shock loadings. Extended aeration activated sludge is used at plants A01, A03, E06, and E21.

Figure 4-3 illustrates the extended aeration activated sludge system used at Plant A03. This process consists of an aeration tank, a secondary clarifier, pumps, and a sludge recycle line. Also in this system, the wasted sludge is centrifuged from the clarifier; the cake is sent to by-product processing at the ethanol plant and the supernatant is recycled to preliminary wastewater treatment. Mixing is accomplished by mechanical aerators as the sludge flows through the length of the basin. Adsorption, flocculation, and oxidation of the organic matter take place during aeration. The solids are settled in the secondary clarifier and the resulting sludge, a mixture of these solids and wastewater, is withdrawn from the bottom of the clarifier. A portion of the settled sludge is recycled to the head of the aeration basin and the excess is sent to a centrifuge for concentration. Effluent from the secondary clarifier is generally low in BOD_5 and TSS. As Table 4-1 indicates, this facility obtains an average reduction in BOD_5 and TSS of 98.7 and 95.0 percent, respectively.

Few operating problems are encountered in the activated sludge processes when the characteristics of the wastewater are consis-

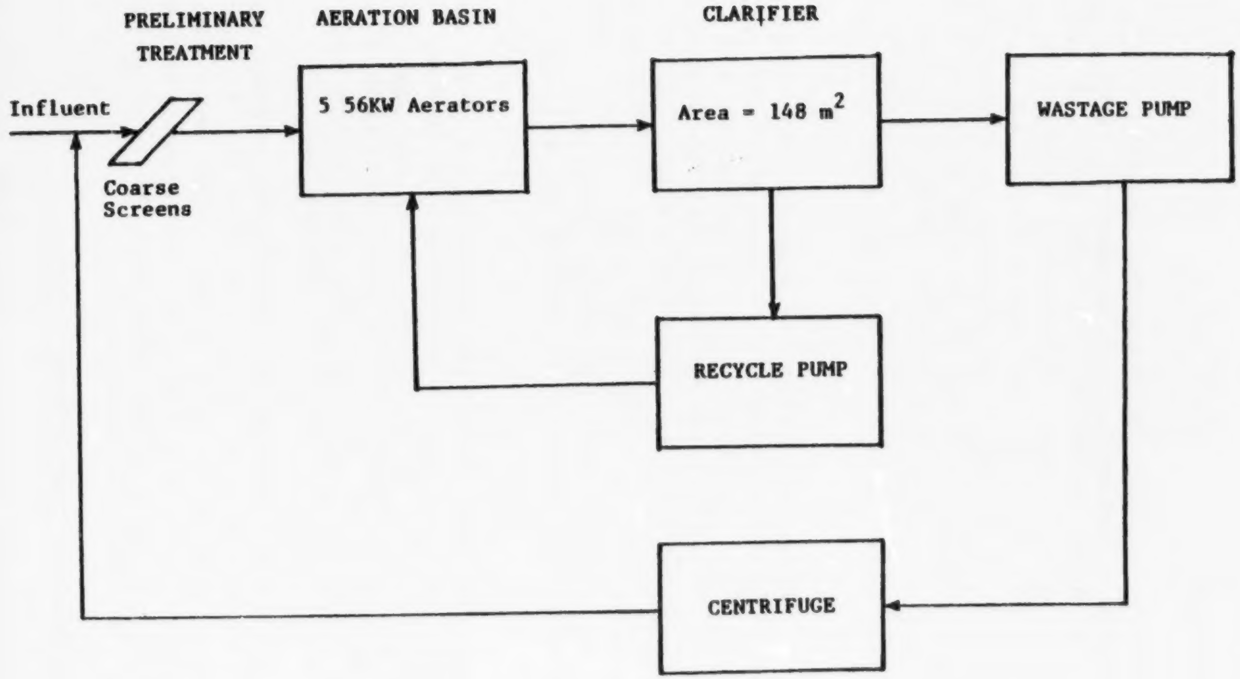

PRELIMINARY TREATMENT
AERATION BASIN
CLARIFIER
Influent
Coarse Screens
5 56KW Aerators
Area = 148 m2
WASTAGE PUMP
RECYCLE PUMP
CENTRIFUGE

Figure 4-3
PLANT A03
ACTIVATED SLUDGE WASTEWATER TREATMENT SYSTEM

tent. However, the performance of the process can be adversely affected by significant changes in temperature, pH, and, depending on the type of activated sludge process, the organic concentration and volumetric flow rate. The microorganism concentration in the tank must also be carefully controlled by adjusting the recycle stream and the amount of sludge wasted. The concentration of nutrients such as nitrogen and phosphorus must also be carefully controlled.

4.5.5 TRICKLING FILTER

The trickling filter is a type of attached growth, biological process for wastewater treatment. It is used by three beverage alcohol plants and is applicable to the treatment of wastewater from ethanol-for-fuel facilities. Trickling filters are often used in series, with the effluent of one filter becoming the influent of the following filter. A portion of the effluent from the last filter is often recycled to the initial filter. There are two types of trickling filters: standard and high rate. These trickling filters differ in the distribution and flow rate per unit surface area of the wastewater over the filter media.

The trickling filter media has relatively small openings and must be preceded by primary treatment to remove gross solids and debris to avoid clogging. A settling tank equipped with scum- and grease-collecting devices are adequate for this function. The trickling filter is comprised of a wastewater distribution system, a vessel containing the filter media, an underdrainage collector, and a partial recirculation system. The suspended solids not removed by the filter and those generated by the sloughing of the microbial layer are removed in a final sedimentation tank.

The operation and maintenance problems associated with the trickling filter are few and can be minimized by proper design considerations. The filter media may be stone or some type of synthetic material such as polyethylene saddles which provide a high surface area per unit volume, a high void space per unit volume, durability, and a resistance to clogging.

Figure 4-4 illustrates the wastewater treatment system used at plant E17 which incorporates two trickling filters in series that follow an aerated lagoon. This system also uses two polishing lagoons (the first aerated and the second not aerated) to achieve an effluent with a BOD_5 reduction of 97.2 percent and a TSS reduction of 76.1 percent (14).

4.5.6 ROTATING BIOLOGICAL CONTACTORS (RBC)

An RBC provides a secondary wastewater treatment technique effected by attached biological growth. RBCs are used at two

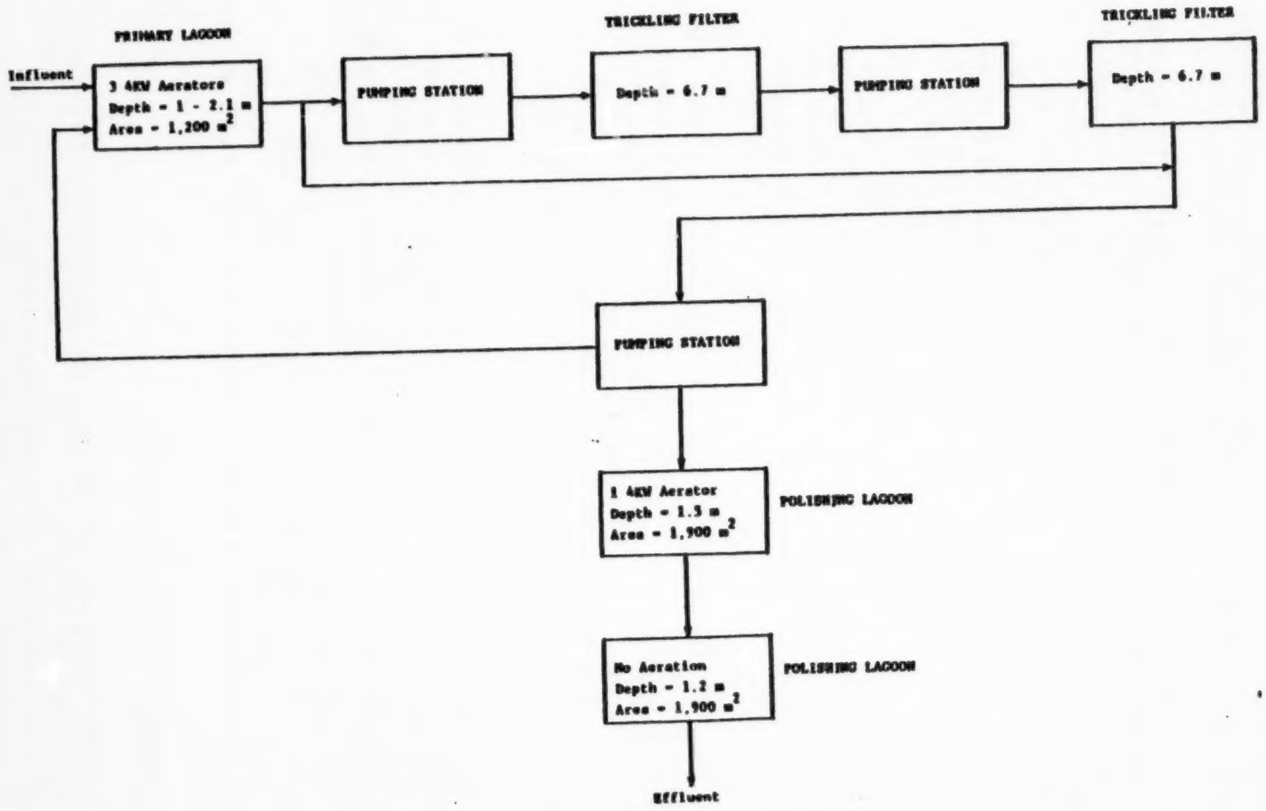

PRIMARY LAGOON
Influent
3 4KW Aerators
Depth - 1 - 2.1 m
Area - 1,200 m2
PUMPING STATION
TRICKLING FILTER
Depth - 6.7 m
PUMPING STATION
TRICKLING FILTER
Depth - 6.7 m
PUMPING STATION
1 4KW Aerator
Depth - 1.5 m
Area - 1,900 m2
POLISHING LAGOON
No Aeration
Depth - 1.2 m
Area - 1,900 m2
POLISHING LAGOON
Effluent

Figure 4-4
PLANT E17
TRICKLING FILTER WASTEWATER TREATMENT SYSTEM

beverage alcohol facilities and are applicable to the treatment of wastewaters from ethanol-for-fuel facilities.

The RBC treatment process is often preceded and followed by clarifiers for solids removal. The closely spaced, molded polystyrene disks that are three to four meters in diameter are mounted on a common shaft. The set of disks is partially (40 percent) submerged in a cylindrically bottomed tank. A series of these tanks with the shafts parallel are positioned between the two clarifiers; no recirculation of sludge is required.

After a biological film on the surface of each disk has grown, the rotating action of the disks (one to two rpm) shears off excess microbial growth, keeps solids in the tank in suspension, and provides oxygen thereby reducing aeration requirements. The attached suspended microorganisms adsorb and assimilate the organic wastes. The thin layer of water that adheres to the surface of the disk as it rotates and the large surface area covered by the biofilm provide a high microorganism to food ratio, and a high degree of oxidation can be carried out quickly; contact times are generally less than one hour. The high degree of oxidation eliminates the necessity of recirculating part of the effluent and therefore pumping requirements are minimal. The sloughed biomass has good settling characteristics and can be easily separated from the waste stream in the final settling tank.

The operating and maintenance problems associated with the RBC process are fewer than those of trickling filters, but startup problems can occur in establishing the biofilm. However, once the system is established, power outages or downtimes of a day or two require only a few hours to bring the system back to equilibrium. The RBC treatment system is usually enclosed to avoid freeze up.

Figure 4-5 shows the wastewater treatment system for Plant E08 which features three RBCs in series. The first RBC receives the effluent from an aerated lagoon and the third RBC discharges to a second aerated lagoon which is followed by three ponds used to settle solids. Finally, the last pond discharges to an air flotation unit used to remove algae and other solids which are difficult to settle. This system achieves BOD_5 and TSS reductions of 97 and 73 percent, respectively. BOD_5 and TSS removals of 50 and 10 percent, respectively, are achieved by the RBC units alone (14).

4.6 TERTIARY TREATMENT

In an ethanol-for-fuel wastewater treatment facility, tertiary treatment would receive the effluent from the secondary treatment system. Based on treated effluent data this secondary effluent typically contains 40 mg/l TSS as biological floc, with

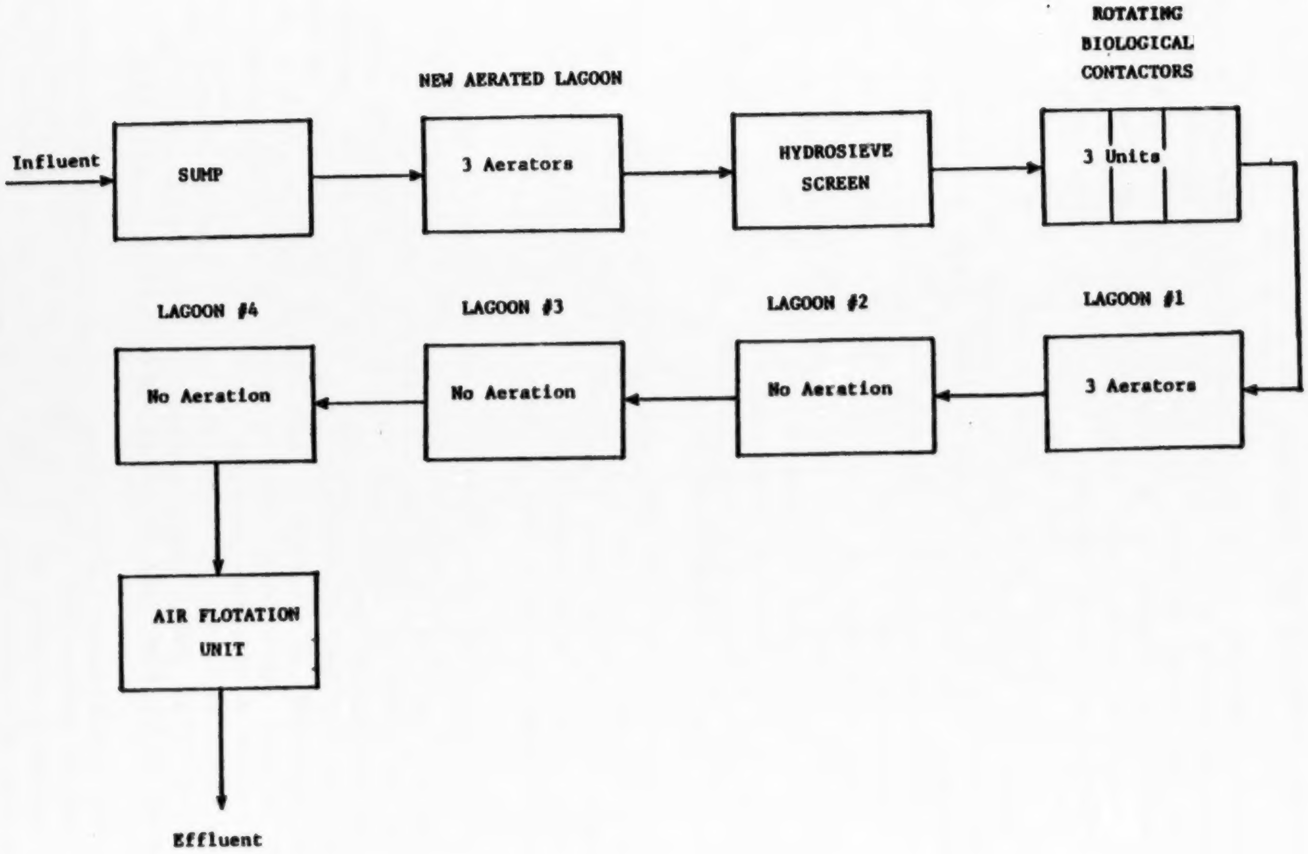

ROTATING
BIOLOGICAL
CONTACTORS
NEW AERATED LAGOON
Influent
SUMP
3 Aerators
HYDROSIEVE
SCREEN
3 Units
LAGOON #4
LAGOON #3
LAGOON #2
LAGOON #1
No Aeration
No Aeration
No Aeration
3 Aerators
AIR FLOTATION
UNIT
Effluent

Figure 4-5
PLANT E08
ROTATING BIOLOGICAL CONTACTOR WASTEWATER TREATMENT SYSTEM

peaks of perhaps 120 mg/l. The effectiveness of tertiary treatment is affected by the origin of the wastewater. Three tertiary treatment systems which are considered applicable to the ethanol-for-fuel industry are granular-media filtration, air flotation, and land application.

4.6.1 GRANULAR-MEDIA FILTRATION

This process consists of passing wastewater through a packed bed of granular material of a depth on the order of one meter or more, with resulting deposition of solids in the granular material. Deposition occurs by a combination of physical mechanisms (i.e., mechanical straining, chance-contact straining, sedimentation, impaction, interception, diffusion, and adhesion) which are discussed by Metcalf and Eddy (26) and Weber (29). The wastewater is diverted from a filter unit, and the unit is taken off line when (1) effluent quality reaches an unacceptable level due to the inability for the given bed depth to hold the solids (breakthrough), (2) a limiting headloss occurs across the bed due to accumulated solids (terminal headloss), or (3) the filters are backwashed on a time cycle basis. After the units are taken off line, the bed is backwashed by passing water upward through the bed to expand it, allowing the shearing action of the water to remove the deposited solids. Backwash is often supplemented by internal or surface water jets or air scouring. The backwash wastewater can be recycled to primary sedimentation or to the biological treatment unit.

Options for flow direction include downflow (conventional), upflow, and biflow. Historically, downflow systems have predominated (27) since they have the advantage of supplied hydrodynamic head. A discussion of the less frequently used upflow and biflow systems can be found in (27).

Particle size and size distribution of the media have major effects on filter performance. Finer media particles possess greater removal abilities than do coarser particles, but they also result in greater headloss per amount of solids removed (27) due to premature bed clogging. The problem of particle size gradation can be alleviated with the use of two or more media. By layering a coarser, less dense medium over a finer, denser one (e.g., coal over sand), a downflow configuration can be combined with a coarse-to-fine gradation in the direction of flow. A further refinement involves multi-media (three media: typically coal over sand over garnet). The gradation can also be eliminated with the use of uniformly sized particles.

As a tertiary treatment technology, granular-media filtration can be expected to reduce levels of 30 mg/l TSS in the influent stream to concentrations of 10 mg/l (27). Supplemental removal of particulate BOD remaining after biological or chemical treatment is achieved by filtration.

Pilot-plant studies for filtration are required to ensure proper filter design since the characteristics of the influent suspended solids affect the performance. Although granular-media filtration has been extensively used in treating the effluent of biological treatment processes at domestic wastewater treatment plants, it has not been used for tertiary treatment purposes in ethanol plant wastewater treatment systems.

4.6.2 AIR FLOTATION

Air flotation is a technique which removes suspended solids in the form of a floating sludge. It can be either purely physical or physical/chemical with the addition of chemical coagulants. Air flotation units generate air bubbles, and the buoyancy of the air bubbles rising through the wastewater lifts suspended materials to the surface. The floated sludge is then skimmed from the surface.

Although air flotation is not widely used in the treatment of ethanol plant wastewater, it is being used by plant E15 to remove algae and suspended solids from its aerated lagoon effluent. This facility employes a dispersed air flotation system which uses diffusers to form air bubbles.

Plant A03 reports that the effluent from its activated sludge system has poor settling characteristics. An air flotation unit, which is relatively compact in size and produces a fairly concentrated sludge, may be a viable alternative to a secondary clarifier for removal of suspended solids from secondary treatment systems such as activated sludge. However, air flotation systems are energy intensive and may produce a floated sludge that is difficult to handle.

4.6.3 LAND APPLICATION OF WASTEWATER

In the land application of wastewater, filtration of solids and biological decomposition are provided by vegetation, the soil surface, and the soil matrix. The three principal methods of land application of wastewater are slow rate, rapid infiltration, and overland flow. Less widely used methods include wetlands and subsurface application (30).

Slow rate treatment is also known as spray irrigation; however, in this case the irrigational effect is secondary to the treatment of wastewater. In slow rate treatment, wastewater is pumped from a reservoir and applied to the soil via a sprinkler or a flooding technique. The disposition of the water is divided between percolation and vegetative uptake and, therefore, both the soil and vegetation are critical in managing the wastewater and its constituents. Organics are reduced by biological oxidation within the top few inches of the soil. Suspended solids can be removed to a level of one mg/l or less by filtration. Volatile solids are biologically oxidized, while mineral solids become a part of the soil matrix. The slow rate process is applicable to agricultural land, grasslands, forest land, and public land such as parks and golf courses.

Rapid infiltration (also known as infiltration-percolation) involves application of the wastewater to a highly permeable soil via sprinklers or flooding basins at a greater rate and upon a smaller area than in slow rate treatment. In rapid infiltration, the soil serves essentially as a filter medium. The water percolates to underdrains, wells, or groundwater; little evaporation or vegetative uptake occurs. Removal of suspended solids and BOD by filtration and straining is nearly complete (30).

Overland flow involves the application of wastewater to the upper areas of a sloped terrain which possesses a low permeability soil or a subsurface barrier to percolation. The wastewater flows down the vegetated surface as a film and is collected at the base for either reuse or discharge. Organics and suspended solids are removed by biological oxidation, sedimentation, and grass filtration (30).

Of the three types of land application processes, the slow rate method is most compatible with crop cultivation. Furthermore, whereas rapid infiltration requires a highly permeable soil and overland flow requires a soil of low permeability, slow rate operates within a wider and more moderate range. Finally, the slow rate process produces effluent of the highest quality.

One ethanol-for-fuel facility in the United States (plant A01) currently practices land application of wastewater; however, this facility is constructing an activated sludge system which will then discharge to a POTW. There is also one beverage alcohol facility (plant E21) which practices land application. Both of these facilities employ the slow rate process; neither overland flow nor rapid infiltration is employed by the ethanol industry.

4.7 DISINFECTION

Disinfection is the elimination of selected disease-causing organisms. This selective elimination differs from sterilization, a process which kills all organisms. Disinfection is necessary if sanitary wastes are sent to the wastewater treatment system. Currently, chlorination is the only practiced means of disinfection.

Chlorination is used for final wastewater disinfection primarily by those plants that combine sanitary wastes with raw wastewater effluents (plants A04, E05, E08, E11, and E12). Disinfection effectiveness generally has been measured by the concentration of the coliform bacteria indicator group that remains after disinfection has taken place. Alternatively, chlorination utilizes a more indirect measure of residual chlorine, which provides presumptive evidence that adequate disinfection was achieved.

Chlorine is highly corrosive when wet; thus, the gas is stored dry, under pressure. It is mixed with water to form an aqueous solution prior to injection to the wastewater stream. The aqueous chlorine solution is mixed with the wastewater in a diffusion chamber; the wastewater plus chlorine then enters a chlorine contact tank, which provides the appropriate detention time before discharge to the receiving water. The chlorine dosage required for disinfection will vary with the quality of the effluent to be treated. To ensure proper disinfection, sufficient chlorine must be added to force the formation of free residual chlorine. The presence of free residual chlorine can easily be monitored to check if adequate chlorine has been added.

One disadvantage of chlorination for disinfection is that it reacts with organic compounds. Groups are formed which often titrate as free chlorine residuals; they possess little or no germicidal ability and give an overestimate of the free residual present. Also, many undesirable chlorinated organics formed during chlorination are suspected to be carcinogenic.

The germicidal effect of chlorine is believed to be due to the reaction of chlorine compounds with the cell membrane of the bacterial cell, thereby stopping the metabolic process. Viruses are also affected, but not in the same correlative, quantifiable way as with bacteria. Among the conditions which affect the germicidal effectiveness are contact time, chlorine concentration, NH_3-N concentration, intensity of light, temperature, pH, number and types of organisms, and the nature of the suspending liquid. In a well-designed contact chamber, the reduction of coliform content should exceed 99 percent, with minimal residual chlorine (less than one mg/l).

4.8 SLUDGE HANDLING

The biological treatment of wastewaters results in the generation of excess biological solids which must somehow be disposed. A portion of the waste material present in the raw wastewater has been concentrated in the form of biological solids; thus, by cleaning the water, a potential solid waste problem is created. This problem has been a recognized area of concern since the advent of biological wastewater treatment, and numerous technologies are available to dewater, stabilize, and recover waste biological sludge.

One typical scenario that is evaluated in this section is shown in Figure 4-6. Waste sludge from the secondary settler is sent to a gravity thickener, where further settling increases the sludge concentration. Concentrated sludge is sent to an aerobic digester, where a portion of the cell matter is oxidized to carbon dioxide. This brings about a reduction in the net mass of waste sludge. The effluent from the aerobic digester is sent to a solids centrifuge, where additional water is removed, resulting in a semi-solid sludge with a solids concentration of up to 20 percent. This sludge can then be trucked to a sanitary landfill for final disposal. Ultimate disposal methods for dewatered and stabilized biosludge as well as for other solid wastes from ethanol facilities are discussed in Section 5 of this document.

4.8.1 GRAVITY SLUDGE THICKENING

A gravity sludge thickener is essentially the same piece of equipment as a secondary settler except that the feed, effluent, and underflow solids concentrations typically found in a sludge thickener are much higher than those found in a secondary settler. There may also be slight differences in the torque rating, sludge rake designs, and effluent weirs.

Influent sludge enters a gravity sludge thickener at concentrations of 5,000 to 25,000 mg/l. The underflow solids concentration in gravity thickeners treating waste activated sludge ranges from 15,000 to 40,000 mg/l. The overflow from the gravity thickener has a suspended solids content of 100 to 350 mg/l and a BOD_5 of 60 to 400 mg/l (26). Due to its high solids and BOD_5 content, the thickener overflow is usually sent back to the aeration basin for further treatment.

4.8.2 SLUDGE DIGESTION

Aerobic digestion can be used to stabilize biological sludge, primary sludge, or a combination. Plant A10 uses separate aerobic digestors for the stabilization of mixtures of excess activated and primary sludges. The digestion process involves oxidation of sludge in either a surface-aerated or a diffused air basin. The major components of an aerobic digester system include a tank, an aeration system, a thickener, and sludge pumps.

Compared to other methods of sludge stabilization (particularly anaerobic digestion) aerobic digestion produces a biologically stable, odorless end product and a supernatant liquor with a lower BOD content than that from anaerobic digestion; this is important in recycling supernatant to avoid overloading the treatment system (Benefield and Randall, 1980). Also, the capital cost of aerobic digestion is generally lower than that for anaerobic digestion and fewer operational problems will

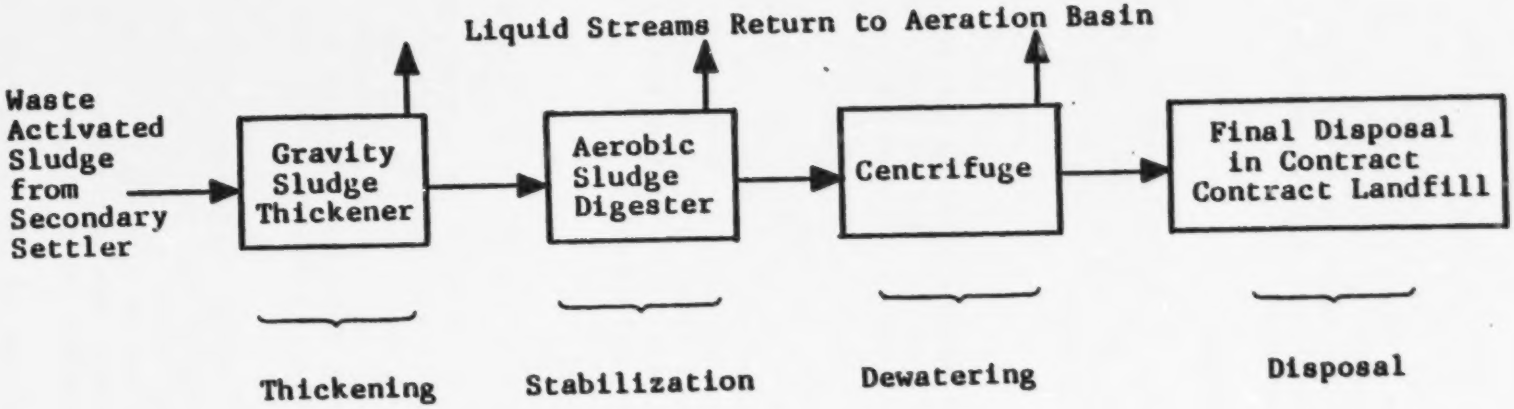

Liquid Streams Return to Aeration Basin
Waste Activated Sludge from Secondary Settler
Gravity Sludge Thickener
Aerobic Sludge Digester
Centrifuge
Final Disposal in Contract Contract Landfill
Thickening
Stabilization
Dewatering
Disposal

Figure 4-6
A TYPICAL SLUDGE HANDLING AND DISPOSAL SYSTEM

occur than with anaerobic digestion; therefore, maintenance and labor costs may be reduced. Finally, aerobically digested sludges have a higher fertilizer value than do those from anaerobic digestion. Disadvantages of aerobic digestion include high power requirements for oxygen supply, and the fact that aerobically digested sludge is often difficult to dewater resulting in a supernatant from subsequent thickening that is high in suspended solids.

4.8.3 SLUDGE DEWATERING

Two methods of sludge dewatering which are used in the beverage alcohol industry and are applicable to the treatment of wastewaters from the ethanol-for-fuel industry are solids centrifuge and sludge drying lagoons.

Solids Centrifuge

The influent to the solids centrifuge enters at a typical concentration of 30,000 mg/l. Solids are forced to the inside wall of the rotating bowl and collected by the rotating conveyor. Liquid centrate passes out the other end of the centrifuge. The centrate will have a TSS concentration in the range of 2,000 to 15,000 mg/l and a BOD_5 concentration between 1,000 and 10,000 mg/l. Thus, this stream is generally sent back to the aeration basin for further treatment. Since the flow rate is so small, no modification of the aeration basin design is required. Solids leave the centrifuge at 10 to 35 percent solids. Sludge at this concentration is semi-solid and can easily be trucked to a landfill for final disposal.

Sludge Drying Lagoons

Sludge drying lagoons provide a nonmechanical means of dewatering the waste sludge produced during biological wastewater treatment. Before the sludge is pumped into the lagoon, it must be digested for stabilization and reduction of odor emissions. Although the sludge lagoon itself may provide additional stabilization, the primary function is dewatering. Lagooning is not capital intensive and does not require significant maintenance; however, it is a land-intensive operation, and odor may be a problem.

In a sludge drying lagoon, the digested sludge is pumped into the bottom of the lagoon and left to dry. Evaporation is the primary mechanism by which dewatering occurs, with supernatant removal and permeation of the fill lining contributing minor amounts to dewatering. Any supernatant which exceeds the overflow level is pumped back to the treatment plant.

Depending on the design of the sludge drying lagoon, a high (>30 percent solids) or low concentration of suspended solids in the dewatered sludge can be achieved prior to removal. A high solids concentration sludge is mechanically removed from the lagoon by a front-end loader, and can be used as a soil conditioner or fertilizer. A liquid product with a low concentration of solids can be pumped from the lagoon into tank trucks and land applied.

Residence times for dewatering depend on the sludge depth in the lagoon. After sludge removal, it is recommended that a six-month rest separate emptying and refilling. Therefore, at least two sludge lagoons should be present at any location.

4.8.4 RECOVERY

Grain alcohol producers who recover stillage can also recover the wastewater treatment sludge by incorporating this sludge into by-product grains. In the by-product grain recovery system, thestillage is first screened; the screened solids are concentrated in centrifuges, evaporators, and dryers. The thin liquids from screening are recycled to the ethanol process or sent to wastewater treatment. The sludge produced in wastewater treatment can be dewatered and mixed with the stillage in the dryers, then sold as a by-product cattle feed if sanitary waste from the plant is not sent to the wastewater treatment system. Thus, the recycle of sludge, which has been practiced for many years by the grain alcohol industry, is the preferred option for ethanol-for-fuel producers using grain.

Previous studies of the beverage alcohol industry show that fermentation of sugar feedstocks (cane molasses, citrus molasses, and sugar cane) produces a stillage low in protein content which is not as nutritional as grain stillage. Therefore, the common practice with this low-protein stillage is treatment and/or disposal.

SECTION 5

SOLID WASTE TREATMENT AND DISPOSAL TECHNOLOGIES

For many ethanol-for-fuel producers that process grain, it will be profitable to recycle and reuse or recover for sale as by-products all wastes associated with ethanol production. However, if the wastes are not recovered, the distiller must comply with Subtitle D (RCRA 4000 Series) regulations which require nonhazardous solid wastes to be disposed of by sanitary landfill. Application of this waste to land used for growing food chain crops is acceptable because excessive levels of heavy metals (lead, cadmium) are not found in the waste. Although no analysis for PCB's was performed, those compounds are not expected to be present based on best engineering judgment.

Table 5-1 presents the treatment and disposal technologies for solid waste currently used in the fermentation ethanol industry. These technologies are used in many industries and are adequate to effectively treat ethanol process wastes.

5.1 RECYCLE/REUSE

Ethanol-for-fuel producers who recover stillage can also recover the wastewater treatment biosludge by incorporating this sludge into by-product grains. However, the sludge may be reclaimed only if sanitary wastes have not been incorporated into the wastewater treatment system.

In the by-product grain recovery system, the stillage is first screened; the screened solids are then concentrated in centrifuges, evaporators, and dryers. The dewatered, stabilized biosludge can be mixed with the stillage in the dryers, then sold as a by-product cattle feed.

The recycle of sludge, which has been practiced for many years by several beverage alcohol producers, is the preferred option for ethanol-for-fuel producers using grain. The cost of sludge recovery is offset by the sale of the recovered sludge as by-product. Also, sludge recovery would require little capital cost since the equipment used is already installed for by-product processing.

Previous studies of the beverage alcohol industry show that fermentation of sugar feedstocks (cane molasses, citrus molasses, and sugar cane) produces a stillage low in protein

Table 5-1

TREATMENT AND DISPOSAL TECHNIQUES FOR ETHANOL PLANT SOLID WASTES

Potential Solid Wastes	Treatment Technology	Disposal/Management Practices
Biosludge	Dewatering, Aerobic or Anaerobic Digestion, Concentration	Land Application/Landfill/Contract Hauling
	Dewatering, Aerobic Digestion, Lagooning	Land Application/Landfill/Contract Hauling
	Dewatering	Inclusion in By-Products (Reclaiming)
	Dewatering	Land Application
Stillage from Beer Still	Concentration and/or Drying	Sold as Animal Feed
	Aerobic or Anaerobic Digestion	Land Application/Landfill/Contract Hauling
Process Wastewater	Aerobic or Anaerobic Digestion	Land Application
	Primary/Secondary	Land Application/Direct or Indirect Discharge/Process Recycle

content which is not as nutritional as grain stillage. Therefore, the common practice with this low-protein stillage is treatment and/or disposal.

In contrast, grain stillage, such as stillage produced at an ethanol-for-fuel facility using corn as a feedstock, will have a higher protein content (approximately 27 percent protein) and therefore a higher market value. Therefore, the common industry practice is to sell the Distiller's Dried Grains (DDG's) as an animal feed supplement. In this way, the reuse of process resources will enhance the animal husbandry segment of society.

5.2 TREATMENT TECHNOLOGIES

Solid wastes which contain large amounts of water (up to 95 percent) such as sludge from biological treatment usually undergo additional treatment prior to disposal. The treatment technologies used in beverage alcohol and ethanol-for-fuel facilities can be classified into two general categories: dewatering and stabilization techniques. Typically a dewatering method is first used to render the waste less cumbersome by reducing the volume of the waste. The concentrated waste is then digested (either aerobically or anaerobically) to produce a stabilized solid waste.

5.2.1 DEWATERING

Three methods of dewatering which are used in the beverage alcohol industry and are applicable to the treatment of solid wastes from the ethanol-for-fuel industry are solids centrifugation, drying lagoons, and gravity thickening. One or more of these methods may be used in order to achieve the desired solids concentration.

Centrifugation. The influent to the solids centrifuge enters at a typical concentration of 30,000 mg/l. Solids are forced to the inside wall of the rotating bowl and collected by the rotating conveyor. Liquid centrate passes out the other end of the centrifuge. The centrate will have a TSS concentration in the range of 2,000 to 15,000 mg/l and a BOD_5 concentration between 1,000 and 10,000 mg/l. Thus, this stream is generally sent back to the wastewater treatment aeration basin for further treatment. Solids leave the centrifuge at 10 to 35 percent solids. Sludge at this concentration is semi-solid and can easily be trucked to a landfill for final disposal, or land applied.

Lagooning. Sludge drying lagoons provide a nonmechanical means of dewatering the waste sludge produced during biological wastewater treatment. Three ethanol production facilities, including one ethanol-for-fuel facility sampled, use sludge lagooning. Before the sludge is pumped into the lagoon, it must be digested for stabilization and reduction of odor emissions. Although the sludge lagoon itself may provide additional stabilization, the primary function is dewatering. Lagooning is not capital intensive and does not require significant maintenance; however, it is a land intensive operation and odor is a continuing problem.

In a sludge drying lagoon, the digested sludge is pumped into the bottom of the lagoon and left to dry. Evaporation is the primary mechanism by which dewatering occurs, with supernatant removal and permetation of the fill lining contributing minor amounts to dewatering. Any supernatant which exceeds the overflow level is pumped back to the treatment plant.

Depending on the design of the sludge drying lagoon, a high or low concentration of suspended solids in the dewatered sludge can be achieved prior to removal. A high solids concentration sludge, which is typically 30 percent or more, is mechanically removed from the lagoon by a front end loader, and used as a soil conditioner or fertilizer. A liquid stream with a solids concentration of 3 to 6 percent is pumped from the lagoon into tank trucks and land applied.

Residence times for dewatering depend on the sludge depth in the lagoon. After sludge removal, it is recommended that a six-month rest separate emptying and refilling. Therefore, at least two sludge lagoons should be present at any location.

Gravity Thickening. A gravity sludge thickener is essentially the same piece of equipment as a secondary settler except that the feed, effluent, and underflow solids concentrations typically found in a sludge thickener are much higher than those found in a secondary settler. There may also be slight differences in the sludge rakes and effluent weirs.

Typically, influent sludge enters the gravity sludge thickener at concentrations of 5,000 to 25,000 gTSS/m^3. The underflow solids concentration in gravity thickeners treating waste activated sludge ranges from 15,000 to 40,000 gTSS/m^3. The overflow from the gravity thickener has a suspended solids content of 100 to 350 gTSS/m^3 and a BOD$_5$ of 60 to 400 gBOD$_5$/m^3 (26). Due to its high solids and BOD$_5$ content, the thickener overflow is usually sent back to the aeration basin for further treatment.

5.2.2 STABILIZATION

Solid wastes are stabilized in order to: reduce pathogens, eliminate offensive odors, and inhibit, reduce, or eliminate the potential for decomposition of organic matter (26). The two most widely used means of stabilization for the ethanol industry are aerobic and anaerobic digestion. These methods biologically reduce the volatile content of the solid waste, thereby reducing the survival of pathogens, release of odors, and decay of organic matter.

Aerobic Digestion. Aerobic digestion can be used to stabilize biological sludge, primary sludge, or other solid wastes. Plant A10 uses separate aerobic digesters for the stabilization of mixtures of excess activated and primary sludges. The digestion process involves oxidation of the solid waste in either a surface-aerated or a diffused air basin. The major components of an aerobic digester system include a tank, an aeration system, a thickener, and sludge pumps.

Compared to other methods of sludge stabilization (particularly anaerobic digestion) aerobic digestion produces a biologically stable, odorless end product and a supernatant liquor with a lower BOD content than that from anaerobic digestion; this is important in recycling supernatant to avoid overloading the treatment system (28). Also, the capital cost of aerobic digestion is generally lower than that for anaerobic digestion and fewer operational problems will occur than with anaerobic digestion; therefore, maintenance and labor costs may be reduced. Finally, aerobically digested sludges have a higher fertilizer value than do those from anaerobic digestion. Disadvantages of aerobic digestion include high power requirements for oxygen supply, and the fact that aerobically digested sludge is often difficult to dewater resulting in a supernatant from subsequent thickening that is high in suspended solids.

Anaerobic Digestion. Anaerobic digestion of secondary wastewater treatment sludges is a very sensitive process. Frequent upsets have led to the use of aerobic digestion (28). Unless all solid wastes from the ethanol production process are consolidated and fed to the anaerobic digester, as with the ANAMET® process, the value of the methane generated is minimal in offsetting the cost of digestion. Two of the beverage alcohol plants surveyed currently use anaerobic digestion.

5.3 DISPOSAL AND MANAGEMENT PRACTICES

Solids which cannot be sold or recycled as well as treated, stabilized sludge must be disposed of safely. Two methods for ultimate disposal of solid wastes are practiced by the beverage alcohol and ethanol-for-fuel industries: contract hauling to a landfill and land application.

Contract Hauling to a Landfill. Options for solid waste disposal by landfill for wastes which have been stabilized to reduce odor and sufficiently dewatered for handling purposes (≥ 20 percent solids) (31) include handling and disposal by the ethanol producing facility on-site, contract hauling and placement on-site, and contract hauling to a landfill site not owned by by the ethanol facility. The common practice to date for beverage alcohol plants which produce a secondary treatment sludge is to hire a contractor to remove and dispose of the solid waste.

The economics of the disposal of industrial wastes by contract methods are a function of location, method of disposal, and the distance from the plant to the disposal site. Sanitary landfill of a solid waste represents a relatively inexpensive form of disposal (32).

Land Application. Stabilized sludge may be land applied in either liquid or semi-solid form. If applied as a liquid, the sludge contains 90 to 97 percent water. If applied as a semi-solid, the sludge contains 60 to 80 percent water. Currently, only one ethanol-for-fuel plant in operation uses land application as a means of sludge disposal.

According to Culp (33), there are two approaches for land application of sludge: (1) apply the sludge to land used for growing agricultural products or other vegetation, or (2) dedicate an area to sludge disposal with no attempt to grow crops. The advantages of using farmland for disposal are the use of nutrients in the sludge such as nitrogen and phosphorus. Care must be taken, however, to avoid pollution of the ground water or heavy metals buildup in the soil and food chain. Heavy metals buildup can be controlled by monitoring the loading rate at which the sludge is applied and periodically testing the soil for heavy metals buildup. The sludge loading rate can then be adjusted, as required to comply with development of the regulations. Although application of sludge to forest or agricultural land poses possible health, safety, and odor problems, it might be the most feasible method of ultimate sludge disposal/management from an economic as well as environmental point of view.

SECTION 6

COST, ENERGY, AND NONWATER QUALITY ASPECTS OF WASTEWATER TREATMENT

In order to assess the overall economic impact of pollution control on the ethanol-for-fuel industry, an engineering analysis was conducted to determine: (1) the typical wastewater treatment problems of the industry, (2) the applicable treatment technologies, (3) the cost and energy requirements of these technologies, (4) the effectiveness of these technologies in reducing pollutant discharges from the industry, and (5) the nonwater quality impact from the proposed regulations.

An economic impact analysis was also performed to investigate the ability of industry to pay the cost of wastewater treatment. The results of this analysis for the ethanol-for-fuel industry are beyond the scope of this document and are presented in a separate EPA document (34).

6.1 MODEL PLANT COSTING

6.1.1 MODEL PLANT CONCEPT

In order to conduct an economic impact analysis of an industry, model plants are developed. A model plant is an engineering concept useful in attempting to assess overall industry costs from technologies which must be designed on a plant-specific basis. Rather than calculate the individual cost of installing wastewater treatment systems at each plant in the industry and summing these costs, the Agency breaks the plants down into groups and lets each group of plants be represented by a model plant.

To calculate the total industry cost of installing a particular technology using the model plant concept, the cost of installing the technology at each of the model plants is first estimated. Since the model plants cover the same general range of production capacities as the real plants, any economies-of-scale or other size-related effects on the cost of the technology are incorporated in the cost estimates. The total cost to the industry is calculated by multiplying the cost of a given technology for a model plant by the number of real plants that the model plant represents.

6.1.2 SIZE DISTRIBUTION OF ETHANOL-FOR-FUEL MODEL PLANTS

The existing ethanol-for-fuel industry and future growth trends were described in Section 2, Industry Profile. For this study which was performed in 1981, it was assumed that a very substantial increase in the number of ethanol plants was expected in the next 10 years, with a wide range of production capacities. The plants were classified as new or existing plants. Existing plants include those which are in operation as well as those under construction. The new plants include those for which construction is initiated after this study. The proposed facilities discussed in the industry profile were used to characterize the new plants.

After a thorough review of all the available information on new and existing plants, five model plant production capacities were selected as indicated in Table 6-1. These sizes were selected because they covered the full range of expected plant sizes and best represent the distribution of plants. The number of plants of each size for each plant type is shown in Table 6-1. In 1981 there were 15 currently operating ethanol-for-fuel facilities and 35 under construction; there were 42 proposed plants in some stage of discussion or planning.

6.1.3 MODEL PLANT WASTEWATER CHARACTERISTICS

Typical characteristics of the raw wastewater produced by an ethanol-for-fuel plant are presented in Table 6-2. These characteristics were used to represent the untreated effluent in all of the treatment system design work presented here. Table 6-2 was prepared by analyzing all the available data on ethanol-for-fuel untreated effluent including: (1) long-term data (six months or more) available from four ethanol plants, (2) EPA's sampling data as discussed in Section 3, and (3) various sources from the literature (14,25,35,36).

The available data for the facilities examined indicate wide variation in wastewater characteristics; influent BOD_5 ranges from 500 to 2,400 mg/l with an industry mean of 1,406 mg/l. As indicated in Table 6-2, a value of 1,500 mg/l was selected to represent the untreated effluent BOD_5 concentration for the model plants. Values for influent TSS and the other parameters listed in Table 6-2 were selected in a similar manner.

There was no information available which indicated that wastewater concentration varied as a function of size. Thus, the raw wastewater composition shown in Table 6-2 has been assumed to describe the wastewater at all five model plants.

6.1.4 MODEL PLANT FLOW RATES

A wastewater treatment plant design is based on both the raw wastewater concentration and flow rate. To assign a wastewater

Table 6-1

ETHANOL-FOR-FUEL PLANT SIZE DISTRIBUTION

Classification	NUMBER OF PLANTS IN EACH MODEL PLANT SIZE CATEGORY					
	Ethanol Production 11,400 m^3/yr 3 x 10^6 gal/yr	Ethanol Production 37,900 m^3/yr 10 x 10^6 gal/yr	Ethanol Production 75,700 m^3/yr 20 x 10^6 gal/yr	Ethanol Production 189,000 m^3/yr 50 x 10^6 gal/yr	Ethanol Production 454,000 m^3/yr 120 x 10^6 gal/yr	Total
Existing						
In Operation	10	2	1	2	0	15
Under Construction	16	10	4	3	2	35
Subtotal	26	12	5	5	2	50
New						
Proposed	7	11	17	6	1	42
Total	33	23	22	11	3	92

Table 6-2

UNTREATED EFFLUENT CHARACTERISTICS USED IN THE DESIGN AND COSTING OF WASTEWATER TREATMENT SYSTEMS FOR ETHANOL-FOR-FUEL PLANTS

	Concentration (mg/l)
Total BOD_5	1,500
Dissolved BOD_5	1,100
Total Suspended Solids (TSS)	500
Total Kjeldahl Nitrogen (TKN)	3
Ammonia (NH_4-N)	0
Total Phosphorus	7
pH range	4-11

flow rate to each of the five model plants, a general relationship between wastewater flow rate and plant production capacity was developed. The data available for the development of model plant flow rates are presented in Table 6-3. As shown in Table 6-3, the data consist of average wastewater flow rate and average ethanol production for a total of 18 facilities, including both ethanol-for-fuel plants and beverage alcohol plants. Also shown in this table is the ratio of wastewater flow rate to ethanol production.

The ratios of wastewater generated to ethanol produced are shown plotted versus plant capacity in Figure 6-1. These data indicate that the wastewater-to-ethanol ratio varies from 6.9 to 33.7 and does not increase or decrease as a function of plant size. This indicates that the wastewater flow rate varies linearly with plant production capacity. The median was selected to be used in relating model plant capacity to wastewater flow. Thus, since the median has a value of 16, each model plant has a wastewater flow rate equal to 16 times the model plant ethanol production capacity.

6.1.5 MODEL PLANTS SUMMARY

A summary of the characteristics of the model plants is presented in Table 6-4. Grain consumption was calculated by assuming that 1,000 kilograms of corn can produce 0.37 cubic meters of ethanol. This is equivalent to assuming 2.5 gallons of ethanol per bushel of corn, where a bushel of corn weighs 56 pounds.

Plants were assumed to be producing alcohol only 330 days per year; the remaining 35 days are devoted to equipment cleaning and shut-down for maintenance and repairs. Thus, in calculating daily wastewater flow from yearly ethanol production, it was assumed that the entire yearly production of ethanol was produced in only 330 days. On the other hand, wastewater treatment O&M costs were calculated on the basis of 365 days per year. This assumes wastewater flow continues even during periods of no ethanol production (e.g., during plant cleanups).

The wastewater flow rate for each of the model plants was calculated by assuming a wastewater-to-ethanol ratio of 16, as discussed in the section on the flow prediction. These flow rates, along with the concentration values given in Table 6-2, were used as the basis for the treatment systems costs presented in the following sections.

In 1981, all beverage alcohol and ethanol-for-fuel producers sold the beer still bottom stillage, either as wet or dried by-products, for animal feed because of a viable market for these high-protein by-products. Further, the market for these by-products was projected to double by 1985 to 1986 (28). Therefore, no cost for treatment or disposal is considered in the cost analyses for the stillage or by-product processing.

Table 6-3

PRODUCTION AND WASTEWATER GENERATION DATA FOR BEVERAGE AND ETHANOL-FOR-FUEL PLANTS

Plant Code	Ethanol Production (m^3/day)	Wastewater Production (m^3/day)	Ratio of Wastewater Production to Ethanol Production (Dimensionless)
A03	200	2,650	13.3
A06	24	170	6.9
A07	70	1,290	18.5
A10	21	340	16.2
E02	30	760	25.0
E04	25	400	15.7
E05	52	830	16.0
E06	43	610	14.2
E07	47	570	12.0
E08	32	610	19.1
E09	230	7,650	33.7
E11	45	1,100	24.4
E12	44	820	18.6
E13	90	1,320	14.7
E15	23	380	16.2
E17	23	380	16.5
E18	23	350	15.3
E19	118	1,550	13.1

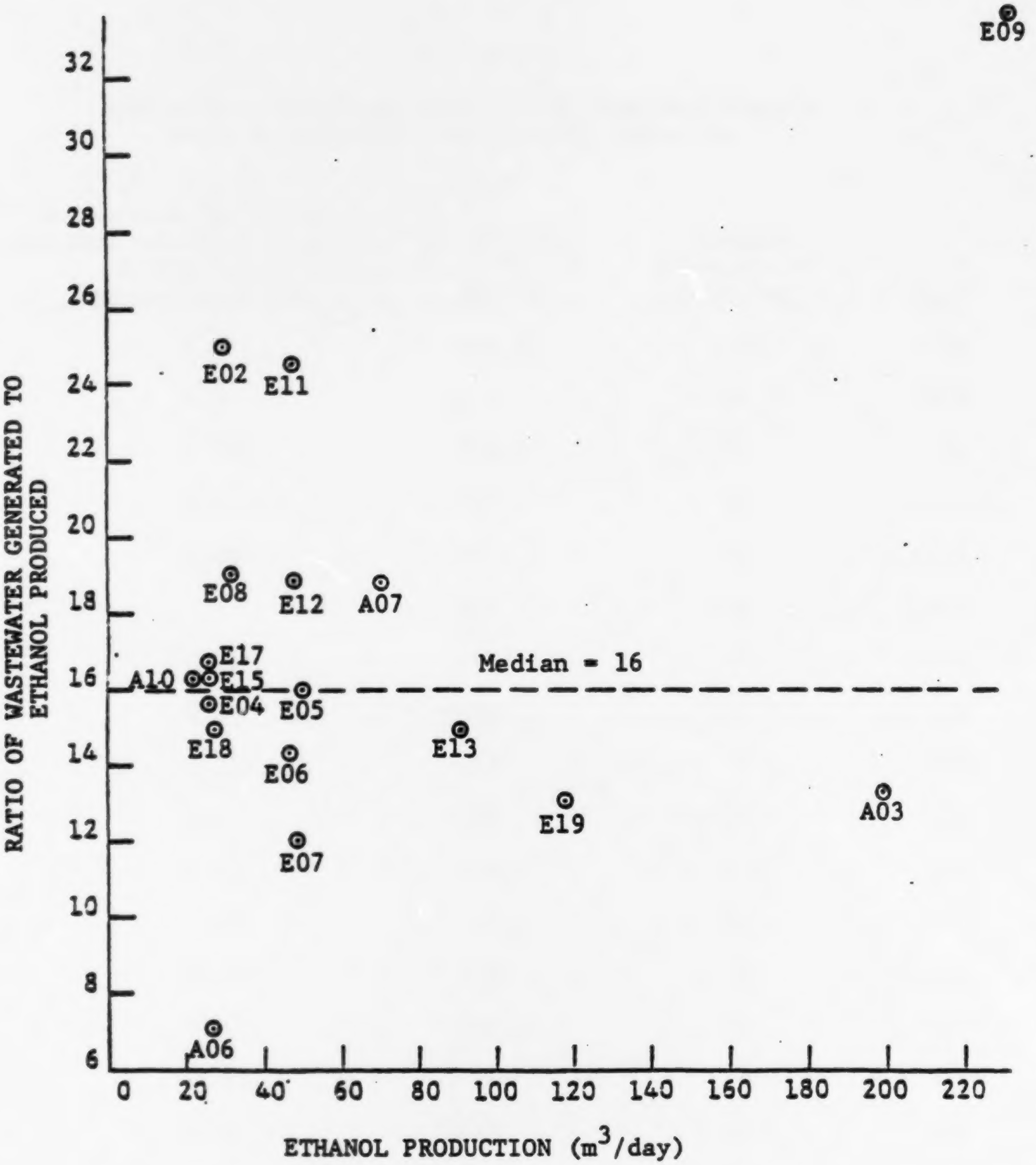


Figure 6-1

RATIO OF WASTEWATER GENERATED TO ETHANOL PRODUCED VERSUS ETHANOL PRODUCTION

Table 6-4

SUMMARY OF MODEL PLANT CHARACTERISTICS

Model Plant Number	Grain Consumption		Ethanol Production		Wastewater Flow Rate	
	(tons/day)	(10 kg/day)	(10 gal/yr)	(m /yr)	(10 gal/day)	(m /day)
1	10.2	92.8	3	11,400	0.15	560
2	340	309	10	37,900	0.49	1,860
3	679	617	20	75,700	0.98	3,720
4	1,705	1,550	50	189,000	2.46	9,310
5	4,092	3,720	120	454,000	5.90	22,300

The characteristics of the biosludge and the amount produced at each facility were based on the model plant wastewater treatment system design. The biosludge from the secondary clarifier has a solids concentration of 10,000 gTSS per cubic meter (one percent solids). Table 6-5 indicates the estimated sludge production from the clarifier for the wastewater treatment options developed for the five model plants.

6.2 TREATMENT OPTIONS FOR COST EVALUATION

6.2.1 WASTEWATER TREATMENT OPTIONS

There are a wide variety of treatment technologies which are appropriate for the wastewaters produced by an ethanol-for-fuel plant. Technologies differ with respect to cost and final effluent quality. Four different direct discharge treatment options were selected for detailed economic evaluation:

Option 1 - Use of aerated lagoons for secondary treatment.

Option 2 - Use of activated sludge for secondary treatment.

Option 3 - Use of aerated lagoons for secondary treatment, followed by granular media filtration.

Option 4 - Use of activated sludge for secondary treatment, followed by granular media filtration.

Aerated lagoons and activated sludge are both widely used in the beverage alcohol and ethanol-for-fuel industries. Granular media filtration can follow either aerated lagoons or activated sludge and will bring about significant additional suspended solids removal (40 to 50 percent).

No treatment options have been considered for indirect dischargers (those who discharge their wastewaters to publicly owned treatment works). Based on the analytical data presented in Section 3, no pollutants are present in ethanol-for-fuel wastewaters which would upset or interfere with the operation of a publicly owned treatment work. However, developers of an ethanol-for-fuel plant should consult the general pretreatment requirements contained in 40 CFR, Part 403 to ensure that such standards are met.

6.2.2 SOLID WASTE TREATMENT OPTIONS

As identified in Section 5.3, there were four methods practiced by the ethanol-for-fuel industry to treat and dispose of biosludge in 1981.

1. Dewatering, stabilization, further dewatering; and either contract hauling, landfilling, or land application.

Table 6-5

BIOSLUDGE PRODUCED DURING WASTEWATER TREATMENT FOR ETHANOL FACILITIES

Model Plant Alcohol Production Capacity m^3/Year (10 gal/yr)	Sludge Produced m^3/Year	Treated Sludge to Landfill (1,000 kg/yr)
11,400 (3)	8,180	139
37,900 (10)	27,380	462
75,700 (20)	54,750	945
189,000 (50)	138,700	2,355
454,000 (120)	328,500	5,640

2. Dewatering, stabilization, lagooning; and either contract hauling, landfilling, or land application.

3. Dewatering, inclusion in by-products.

4. Dewatering, land application.

For the purpose of performing the cost analysis, the first treatment and disposal option is selected since it is the most capital intensive option and would provide the most conservative or "worse case" impact.

The actual treatment train used in the cost analysis consists of a gravity thickener for dewatering, an aerobic digester for stabilization, and a centrifuge for further dewatering. The assumptions used in the design of the treatment system are presented in Table 6-6. The cost used for contract hauling was $66 per metric ton of sludge.

6.3 CAPITAL AND OPERATION AND MAINTENANCE COSTS

6.3.1 WASTEWATER TREATMENT COSTS

Capital costs of wastewater treatment for all four treatment options are shown as a function of plant size, for new and existing plants, in Tables 6-7 and 6-8, respectively. The costs for existing plants include a retrofit cost penalty to account for the extra cost of building a wastewater treatment system on the site of an existing ethanol-for-fuel plant.

O&M costs of wastewater treatment for all four treatment options are shown as a function of plant size, for both new and existing plants, in Table 6-9. O&M costs include the cost of labor, maintenance materials, electricity, chemicals, and sludge disposal. The annualized cost of capital is not included.

All costs are in March 1980 dollars. Adjustments for inflation can be made using the EPA SCCT cost index which had a value of 162.2 in March 1980.

A schematic flow diagram for treatment Options 1 and 3 is shown in Figure 6-2. The aerated lagoon system (Option 1) includes raw wastewater pumps, an equalization basin and associated pumping, a neutralization system consisting of acid and lime feed systems and mix tanks, ammonia and phosphoric acid feed systems for nutrient addition, an aerated lagoon, a secondary clarifier, and a centrifuge for solids dewatering. The Option 3 system is identical to the Option 1 system except that the effluent from the secondary clarifier receives additional treatment by granular media filtration.

Table 6-6

ASSUMPTIONS USED IN THE DESIGN OF THE SOLID WASTE HANDLING SYSTEM

Gravity Thickener (22)

Solids Loading Rate (SLR): 20,000 g TSS/m^2/day

Underflow Concentration: 30,000 g TSS/m^3

Aerobic Digester

Reduction in Volatile Suspended Solids: 35 percent

Centrifuge

Solids Capture: 80 percent

Table 6-7

SUMMARY OF WASTEWATER TREATMENT CAPITAL COSTS FOR NEW ETHANOL-FOR-FUEL FACILITIES

	CAPITAL COST* (10^3 DOLLARS)				
Treatment Option	Ethanol Production 11,400 m^3/yr 3 x 10^6 gal/yr	Ethanol Production 37,900 m^3/yr 10 x 10^6 gal/yr	Ethanol Production 75,700 m^3/yr 20 x 10^6 gal/yr	Ethanol Production 189,000 m^3/yr 50 x 10^6 gal/yr	Ethanol Production 454,000 m^3/yr 120 x 10^6 gal/yr
Option 1 Aerated Lagoon	1,270	--	4,750	--	15,600
Option 2 Activated Sludge	1,630	2,760	4,180	7,630	15,800
Option 3 Aerated Lagoon plus Granular Media Filtration	1,390	--	5,090	--	16,300
Option 4 Activated Sludge plus Granular Media Filtration	1,770	2,990	4,550	8,190	16,700

*Note: All costs are in March 1980 dollars. Capital cost does not include interest during construction which will increase capital costs 5 to 10 percent depending on interest rate and time period used.

Table 6-8

SUMMARY OF WASTEWATER TREATMENT CAPITAL COSTS FOR EXISTING ETHANOL-FOR-FUEL FACILITIES

	CAPITAL COST* (10^3 DOLLARS)				
Treatment Option	Ethanol Production 11,400 m^3/yr 3 x 10^6 gal/yr	Ethanol Production 37,900 m^3/yr 10 x 10^6 gal/yr	Ethanol Production 75,700 m^3/yr 20 x 10^6 gal/yr	Ethanol Production 189,000 m^3/yr 50 x 10^6 gal/yr	Ethanol Production 454,000 m^3/yr 120 x 10^6 gal/yr
Option 1 Aerated Lagoon	1,620	--	6,070	--	19,800
Option 2 Activated Sludge	2,010	3,400	5,150	9,420	19,600
Option 3 Aerated Lagoon plus Granular Media Filtration	1,810	--	6,510	--	20,900
Option 4 Activated Sludge plus Granular Media Filtration	2,180	3,670	5,610	10,100	20,700

*Note: All costs are in March 1980 dollars. Capital cost does not include interest during construction which will increase capital costs 5 to 10 percent depending on interest rate and time period used.

Table 6-9

SUMMARY OF WASTEWATER TREATMENT O&M COSTS FOR NEW AND EXISTING ETHANOL-FOR-FUEL FACILITIES

	O&M COST* (10^3 DOLLARS/YEAR)				
Treatment Option	Ethanol Production 11,400 m^3/yr 3 x 10^6 gal/yr	Ethanol Production 37,900 m^3/yr 10 x 10^6 gal/yr	Ethanol Production 75,700 m^3/yr 20 x 10^6 gal/yr	Ethanol Production 189,000 m^3/yr 50 x 10^6 gal/yr	Ethanol Production 454,000 m^3/yr 120 x 10^6 gal/yr
Option 1 Aerated Lagoon	154	--	596	--	3,120
Option 2 Activated Sludge	259	570	689	1,390	2,860
Option 3 Aerated Lagoon plus Granular Media Filtration	165	--	627	--	3,170
Option 4 Activated Sludge plus Granular Media Filtration	270	586	719	1,430	2,910

*Note: All costs are in March 1980 dollars. Capital cost does not include interest during construction which will increase capital costs 5 to 10 percent depending on interest rate and time period used.

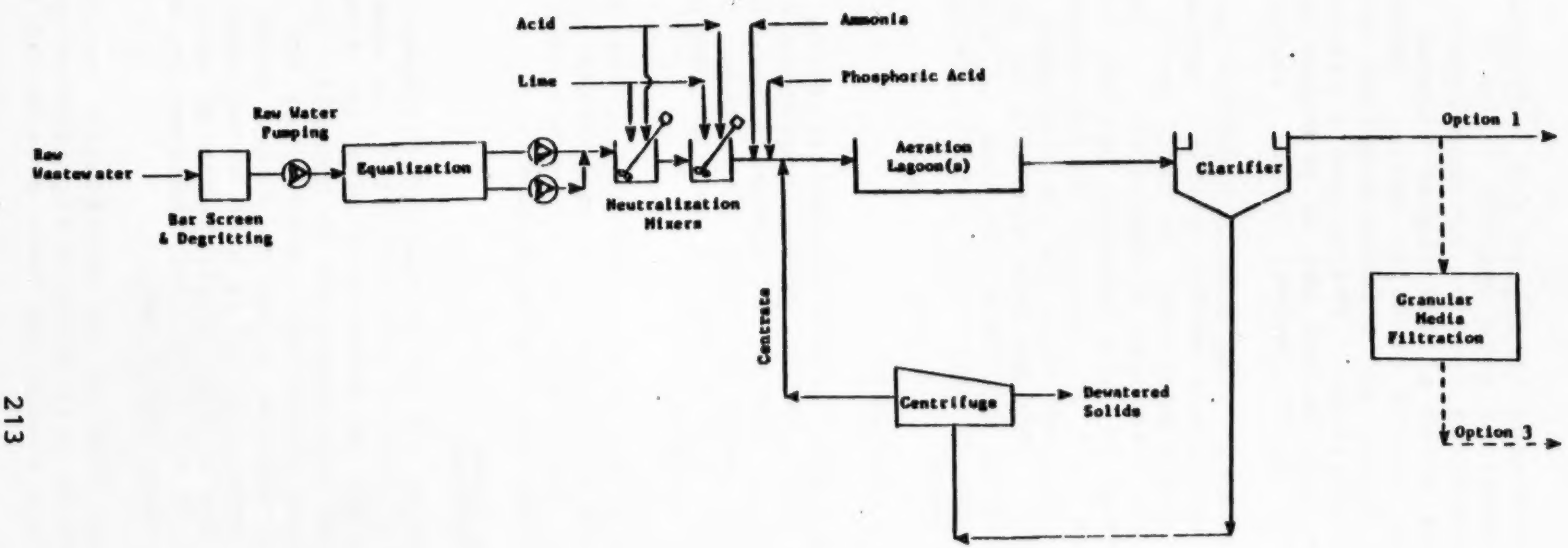

Raw Wastewater
Bar Screen & Degritting
Raw Water Pumping
Equalization
Acid
Lime
Neutralization Mixers
Ammonia
Phosphoric Acid
Aeration Lagoon(s)
Clarifier
Option 1
Granular Media Filtration
Option 3
Centrate
Centrifuge
Dewatered Solids

Figure 6-2
SCHEMATIC DIAGRAM OF TREATMENT OPTIONS 1 AND 3

Options 2 and 4 are illustrated in Figure 6-3. Treatment up to the aeration basin is identical with Options 1 and 3. An activated sludge system differs from an aerated lagoon due to the use of sludge recycle which allows higher biomass concentrations to be maintained in the aeration basin. Waste sludge is sent to a gravity thickener and aerobic digester before dewatering by a solids centrifuge. The Option 4 system differs from the Option 2 system only in the use of granular media filtration for additional solids removal before discharge.

Cost estimates were developed using standard design techniques and published cost data or direct vendor quotes. Assumptions used in the system design are presented in Table 6-10. Cost estimation assumptions are presented in Table 6-11. Note that all capital costs presented in this document exclude interest during construction. The cost of interest during construction varies as a function of interest rate and is discussed in the economic impact study (31). For an interest rate of 10 percent and an amortization period of 30 years, the cost of interest during contruction will add an additional 5 to 10 percent to the capital costs presented here.

6.3.2 SOLID WASTE TREATMENT COSTS

Capital costs for sludge handling for new and existing facilities are presented in Table 6-12. Annual operation and maintenance costs as well as energy requirements for the treatment and disposal of solid waste are also presented. Table 6-5 presented the amount of treated sludge in metric tons per year which must be hauled for landfill.

The only solid waste which has an economic impact for an ethanol production facility is the biosludge from wastewater treatment. Therefore, the costs associated with solid waste handling have been included in the wastewater treatment costs.

6.4 NON-WATER QUALITY ASPECTS

The nonwater quality aspects of the presented treatment options include any solid waste disposal, air pollution, or energy consumption problems that might be associated with the treatment options. The Agency gives consideration to nonwater quality issues in order to minimize cross-media conflicts; for example, creating an air pollution problem while solving a water pollution problem. Energy conservation is also a national priority and the Agency examines the energy requirements of each treatment option to determine if a significant increase in energy required per pound of product would result.

Solid Waste Disposal. All four of the wastewater treatment options previously presented will produce significant quantities of biological sludge. This sludge has been determined to be

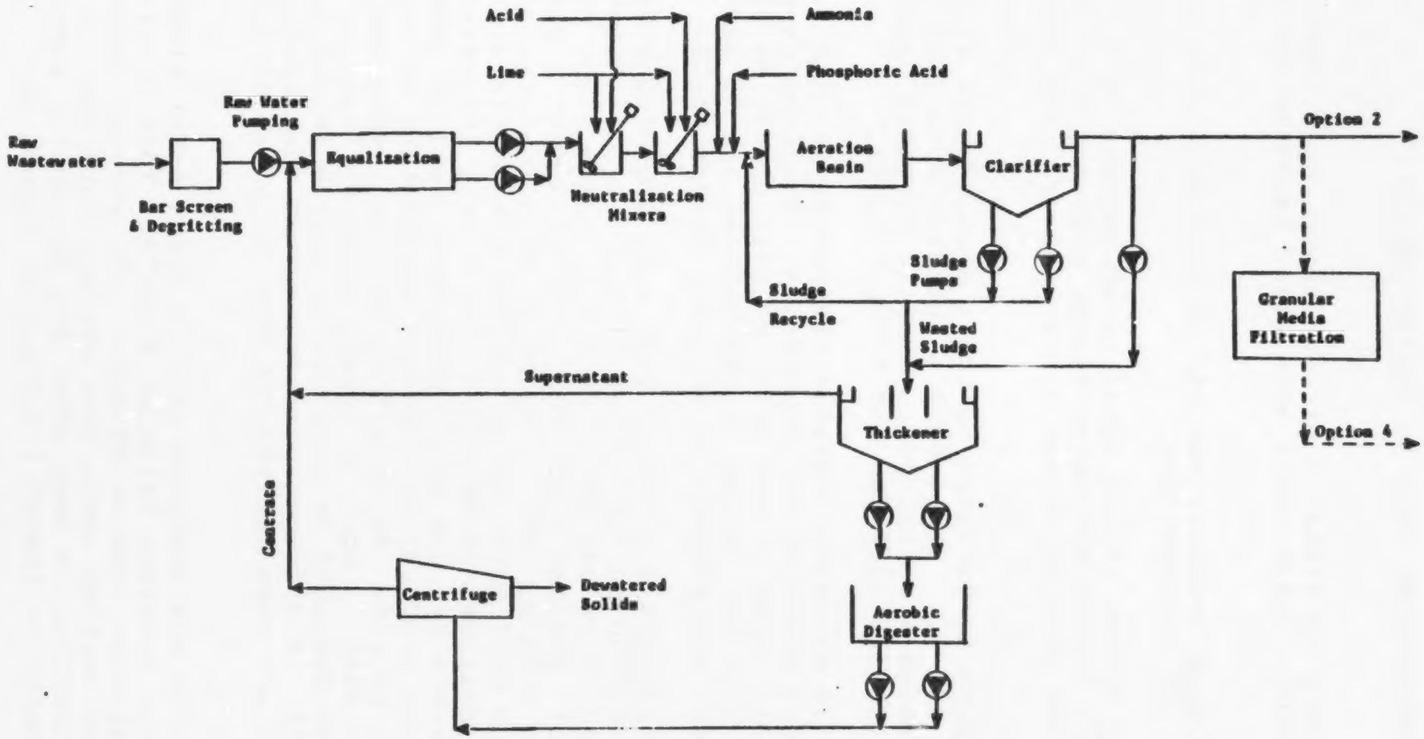

Raw Wastewater
Bar Screen & Degritting
Raw Water Pumping
Equalization
Acid
Lime
Neutralization Mixers
Ammonia
Phosphoric Acid
Aeration Basin
Clarifier
Sludge Pumps
Sludge Recycle
Wasted Sludge
Option 2
Granular Media Filtration
Option 4
Supernatant
Thickener
Aerobic Digester
Centrate
Centrifuge
Dewatered Solids

Figure 6-3
SCHEMATIC DIAGRAM OF TREATMENT OPTIONS 2 AND 4

Table 6-10

ASSUMPTIONS USED IN SYSTEM DESIGN

Preliminary treatment consists of bar screening, grit removal, and flow measurement. These units were sized based on maximum flow rate.

Raw wastewater pumping capacity was set to provide a firm pumping capacity equal to the maximum flow.

Equalization basin volume is set equal to 20 percent of total daily flow volume. In the activated sludge system a concrete basin was used. The aerated lagoon system uses a lined earthen basin.

Neutralization system is designed to treat a wastewater with a pH varying between 4 and 11. Thus, both a sulfuric acid feed system and a lime feed system are included. Average chemical doses over a 24-hour period are 200 mg/l CaO and 47 mg/l H_2SO_4.

Nutrient addition is necessary because wastewater is high in BOD_5 and low in both nitrogen and phosphorus. Required chemical dosages are calculated on the basis of cell growth by assuming the volatile suspended solids in the biomass are 12 percent nitrogen and 2.3 percent phosphorus on a dry weight basis.

Activated sludge system was designed with a 20 day sludge age and a mixed liquor suspended solids (MLSS) of 4,000 mg/l. Kinetic constants for design were estimated from full scale plant data and are as follows: maximum specific growth is 2 day^{-1}; yield coefficient equals 0.45 mg VSS per mg BOD_5; Monod saturation constant equals 100 mg/l BOD_5; decay coefficient equals 0.05 day^{-1}. Secondary settler was designed with a very low overflow rate of 8 cubic meters per day per square meter because available data indicate sludge produced by treating wastewaters of this kind often settles poorly. As an aid to settling, secondary clarifier is dosed with 17 mg/l of ferric sulfate (Fe_2SO_4). Aeration system was designed by considering oxygen demand and mixing requirements. A diffused aeration system was selected and 75 cubic meters of air were applied for each kilogram of BOD_5 removed.

Aerated lagoon system was designed using a first order kinetic model with a kinetic constant value of 2 day^{-1}. This results in a hydraulic residence time of 25 days. The aerated lagoon consists of a lined earthen basin with surface aerators. A cement circular clarifier is used after the lagoon for suspended solids removal. Aerators transfer 2.1 pounds oxygen per horsepower-hour.

Table 6-10 (Continued)

ASSUMPTIONS USED IN SYSTEM DESIGN

Sludge handling system consists of sludge thickener, aerobic digester, and solids centrifuge for the activated sludge system. Sludge thickener size for solids loading of 20 kilograms of TSS per square meter per day. Aerobic digester achieves 35 percent volatile suspended solids reduction. Centrifuge has 80 percent solids capture and produces a final sludge with 20 percent solids.

Granular media filtration used filtration rate of 2 to 5 gallons per minute per square foot.

Table 6-11

ASSUMPTIONS USED IN COST ESTIMATION

1. Date basis for all costs is March 1980 at which time the EPA SCCT Cost Index had a value of 162.2.

2. Cost estimates were developed from direct vendor quotes, material take-off calculations, and the following published data sources: Benjes, 1980; Conway and Ross, 1980; Culp, 1980; EPA a, 1975; Gumerman et. al., 1979; and Patterson and Banker, 1971.

3. Yardwork is 14 percent of total installed unit process costs.

4. Engineering and contingency are each 10 percent of the total direct construction cost.

5. Land cost was assumed to be $15,000 per acre for aerated lagoons and $30,000 per acre for activated sludge.

6. Working capital was assumed to be 20 percent of annual O&M cost.

7. Labor wage is $11.00 per hour direct plus 15 percent for indirect costs (medical, insurance). Net rate is $12.65 per hour.

8. Electricity costs $0.035 per kilowatt-hour.

9. Chemical costs are as follows:

Chemical	Cost
Lime (pebble quicklime)	$ 65/ton
Sulfuric Acid	$ 70/ton
Phosphoric Acid (75% solution)	$ 460/ton
Ammonia (Aqua-ammonia, 30% NH_3)	$ 225/ton
Ferric Sulfate, 94% $Fe_2(SO_4)_3$	$ 146/ton

All costs above include shipping to the plant site.

10. Sludge disposal costs $60/ton including hauling from plant site to landfill.

Table 6-12

COST OF SOLID WASTE HANDLING*

Plant Size (MM gpy)	Capital Cost		O&M Cost ($/yr)	Electricity (Kwhr/yr)
	New Facilities	Existing Facilities		
3	$ 409,700	$ 514,400	57,950	107,520
10	549,100	688,000	105,200	141,300
20	732,800	916,400	175,770	228,700
50	1,059,900	1,318,900	373,750	748,600
100	1,995,900	2,478,300	813,720	1,610,000

*Sufficient land has been provided in the wastewater treatment design for solid waste treatment technologies.

nonhazardous and, in some cases, can be recovered and sold with the by-product grains. If this sludge is not recovered, it is usually dewatered and stabilized before contract hauling to a landfill. No further wastes are generated by sludge treatment. Wastewater overflows from the gravity thickener and solids centrifuge used to dewater the sludge are sent to the aeration basin for treatment. Also, stabilization of the sludge reduces any odors emitted from the thickened sludge. Section 3.7 presented a detailed discussion of solid wastes associated with ethanol-for-fuel production and methods of recovery, treatment, and disposal.

Air Pollution. No serious air pollution problems are anticipated as a result of implementing any of the control technologies evaluated in this cost analysis. Potential odor problems could be encountered in operating secondary biological treatment systems, but this should not be a serious problem when systems are operated properly. Section 3.6 presented a detailed discussion of air pollution problems associated with ethanol-for-fuel production.

Energy Requirements. Table 6-13 presents energy requirements for treatment options 1 through 4. Although energy requirements constitute a major portion of the O&M costs of the treatment system, none of these treatment systems would result in a significant increase in the overall energy requirements of a typical ethanol-for-fuel plant.

Table 6-13

SUMMARY OF WASTEWATER TREATMENT ENERGY REQUIREMENTS NEW AND EXISTING ETHANOL-FOR-FUEL PLANTS

	ENERGY REQUIREMENTS (10^3 kwhrs/yr)				
Treatment Option	Ethanol Production 11,400 m^3/yr 3 x 10^6 gal/yr	Ethanol Production 37,900 m^3/yr 10 x 10^6 gal/yr	Ethanol Production 75,700 m^3/yr 20 x 10^6 gal/yr	Ethanol Production 189,000 m^3/yr 50 x 10^6 gal/yr	Ethanol Production 454,000 m^3/yr 120 x 10^6 gal/yr
Option 1 Aerated Lagoon	1,937	--	10,934	--	67,529
Option 2 Activated Sludge	1,880	5,580	10,700	29,700	58,500
Option 3 Aerated Lagoon plus Granular Media Filtration	2,047	--	11,034	--	67,839
Option 4 Activated Sludge plus Granular Media Filtration	1,990	5,770	10,800	29,800	58,800

GLOSSARY

absolute ethanol: Dehydrated ethyl alcohol of the highest proof obtainable (200° proof), also called anhydrous ethanol.

absorption: The taking up of one substance into the body of another.

acid hydrolysis: A kind of cellulose-to-sugar conversion process which uses acid (sulfurous acid) to break down the cellulose. Urban waste and vegetable residues can be turned into ethanol by this process.

activated sludge: Sludge floc produced in raw or settled wastewater by the growth of zoogleal bacteria and other organisms in the presence of dissolved oxygen and accumulated in sufficient concentration by returning floc previously formed.

activated sludge process: A biological wastewater treatment process in which a mixture of wastewater and activated sludge is agitated and aerated. The sludge is subsequently separated from the treated wastewater (mixed liquor) by sedimentation and wasted or returned to the process as needed.

adsorption: The adherence of a gas, liquid, or dissolved material on the surface of a material.

aerated lagoon: A natural or artificial wastewater treatment pond in which mechanical or diffused-air aeration is used to supplement the oxygen supply.

aerobic: A condition in which free, elemental oxygen is present.

alcohol: A class of organic chemicals composed of carbon, hydrogen, and oxygen which include methanol, ethanol, and other alcohols; most all alcohols will produce a flame when ignited in air.

aldehyde (Webster): Any of various highly reactive compounds typified by acetaldehyde and characterized by the group CHO. A volatile fluid obtained by the oxidation of alcohol.

alkalinity: Alkalinity is a measure of the capacity of water to neutralize an acid.

anaerobic: A condition in which free, elemental oxygen is absent.

anaerobic fermentation: The process whereby chemicals (especially starches and sugars contained in many agricultural crops) are broken down by bacteria and yeasts in the absence of free oxygen to produce alcohols.

anhydrous: Means "without water." The ethanol contained in gasohol is usually anhydrous; even very small amounts of water in ethanol may cause separation of the ethanol gasoline mixture.

apparent proof: The equivalent of proof for ethyl alcohol solutions containing ingredients other than water.

ATF (Bureau of Alcohol, Tobacco and Firearms): Federal agency responsible for the licensing and regulation of alcohol production and sales. A division of the Department of Treasury.

backwashing: The operation of cleaning a filter by reversing the flow of liquid through it and washing out matter previously captured in it.

bar rack: A screen composed of parallel bars, either vertical or inclined, placed in a waterway to catch debris.

barometric condenser: See condenser, barometric.

basin: A natural or artificially created space or structure which has a shape and character of confining material that enables it to hold water.

beer: The liquid containing mash which has been fermented in an ethanol-for-fuel plant. It contains 10 to 12 percent ethanol.

beer still: A distillation column in which the beer is stripped of the ethanol, producing an 80 percent ethanol product.

benzene recovery column: A column in which the benzene and ethanol are stripped from an ethanol/water rich inlet. The benzene and ethanol are recycled to the dehydration column while the residual water is sent to the waste treatment plant.

biochemical: Pertaining to chemical change resulting from biological action.

bio-degrade: To biologically reduce the complexity of a chemical compound or substance by splitting off one or more groups or large component parts; decompose.

bio-degradability: The destruction or mineralization of either natural or synthetic organic materials by microorganisms.

biological filter: A bed of stone or other medium through which wastewater flows or trickles that depends on biological action for its effectiveness.

biological wastewater treatment: Forms of wastewater treatment in which bacterial or biochemical action is intensified to stabilize, oxidize, and nitrify the unstable organic matter present. Intermittent sand filter, contact beds, trickling filters, and activated sludge processes are examples.

biomass: Living matter, vegetation or any plant material, now in a state of decay, including animal and human waste, that may be used to produce energy.

BOD (Biochemical Oxygen Demand): A semiquantitative measure of biological decomposition of organic matter in a water sample. It is determined by measuring the oxygen required by microorganisms to oxidize the contaminants of a water sample under standard laboratory conditions. The standard conditions include incubation for five days at 20°C.

BOD load: The BOD content, usually expressed in mass or weight per unit time, of wastewater.

boiler blowdown: Discharge from a boiler system designed to prevent a buildup of dissolved solids.

boiler feedwater: Water used to generate steam in a boiler. This water is usually condensate, except during boiler startup, when treated fresh water is normally used.

brine: Concentrated salt solution remaining after removal of distilled product.

brix: A reading on a hydrometer scale which represents weight percentage of sugar in solution at a specified temprature.

bulking sludge: An activated sludge that settles poorly because of a low density floc.

bushel: The weight of grain contained in a bushel varies by industry as follows: (a) Barley = 22 kg (48 lb) (b) Malt = 15 kg (45 lb) (c) Distillers Grain = 25 kg (56 lb).

capital costs: Costs which result in the acquisition of, or the addition to, fixed assets.

cellulosic: Refers to chemicals contained in crop stalks, forest residues, and substantial portions of urban wastes; treatment of cellulosic materials with acids or enzymes will yield fermentable sugars which can be converted to alcohols.

clarification: Removing undissolved materials from a liquid by settling, filtration, or flotation.

clarifier: A unit of which the primary purpose is to reduce the amount of suspended matter in a liquid.

coagulation: In water and wastewater treatment, the destabilization and initial aggregation of colloidal and finely divided suspended matter by the addition of a floc-forming chemical or by biological processes.

COD (Chemical Oxygen Demand): Its determination provides a measure of the oxygen demand equivalent to that portion of matter in a sample which is susceptible to oxidation by a strong chemical oxidant.

column bottoms: The less volatile component in a distillation column comes off the bottom while the more volatile component is vaporized and comes off the top. The less volatile component makes up the column bottoms.

comminute: To reduce to minute particles or fine powder; to break up, chip, or grind; to pulverize.

composite sample: A combination of samples taken at selected intervals to minimize the effect of the variability of individual samples and are proportional to the flow at time of sampling.

concentration: The amount of a given substance in a unit volume. For wastewater, normally expressed as milligrams per liter (mg/l).

condensate: Water resulting from the condensation of vapor, as in an evaporator.

condenser: A heat exchange device used for condensation.

barometric:	Condenser in which the cooling water and the vapors are in physical contact; the condensate is mixed in the cooling water.
surface:	Condenser in which heat is transferred through a barrier that separates the cooling water and the vapor. The condensate can be recovered separately.

continuous fermentation: A fermentation process in which the yeast is separated from the fermented mash and recycled to the fermenters.

conversion ratios:

1. 1 bushel of corn yields 2.73 gallons of 190 proof ethanol.

2. 1 bushel of corn yields 2.55 gallons of 200 proof ethanol.
3. 1 barrel = 42 gallons.
4. 1 bushel of corn weighs 56 pounds.
5. 1 gallon of ethanol weighs 6.6 pounds.
6. 1 ton of crop residue contains .8 tons of fermentable sugar.
7. 1 ton of fermentable sugar yields .5 tons of 200 proof ethanol.

cooling tower blowdown: Discharge from a cooling tower system designed to prevent a buildup of dissolved solids.

decanting: Separation of liquid from solids by drawing off the upper layer after the heavier material has settled.

dehydration: The removal of all water from the ethanol. This process must be accomplished by altering the azeotrope by the addition of a third compound.

dehydration agent: That compound used to alter the water/ ethanol azeotrope to permit the dehydration of the ethanol.

denaturant: A material added to ethanol to destroy its character as beverage.

denatured ethanol: Ethanol which has been denatured pursuant to completely denatured ethanol formulas prescribed by federal regulations. Unfit for human consumption.

digestion: See sludge digestion.

dissolved solids: See solids.

distillate: Condensed vapors from the solution which form the product of distilling.

Distiller's Dried Grains (DDG): A high protein (25 to 30 percent) by-product of the grain fermentation process which is used for animal feed; large scale ethanol production would substantially increase DDG by-products.

distillation: A process of evaporation and recondensation used for separating liquids into various fractions according to their boiling points or boiling ranges.

D.O. (Dissolved Oxygen): A measure of the amount of free oxygen in a water sample. It is dependent on the physical, chemical, and biochemical activities of the water sample.

DOE: Department of Energy.

DOI: Department of Interior.

doubling: Redistilling spirits to improve strength and flavor.

"effect": In systems where evaporators are operated in series of several units, each evaporator is known as an effect.

EGD: Effluent Guidelines Division

energy economy: Heat release; Btu's per gallon; often expressed in miles/100,000 Btu's.

entrainment: The entrapment of liquid droplets in the water vapor produced by evaporation.

enzyme: Catalytic chemical substances responsible for alcoholic fermentation.

enzyme hydrolysis: A technology which uses enzymes in yeast and mildew to break down cellulose to sugar.

EPA: United States Environmental Protection Agency.

equalization basin: A holding basin in which variations in flow and composition of a liquid are averaged. Such basins are used to provide a flow of reasonably uniform volume and composition to a treatment unit.

ethanol (ethyl alcohol): The common name for the hydroxyl derivative of the hydrocarbon ethane which is also known as carbinol, ethyl hydroxide, grain alcohol, fermentation alcohol, cologne spirits, and spirits of wine.

ethanol-for-fuel plant: Those commercial-size (greater than one million gallons per year) facilities that convert biomass (via fermentation) to ethanol for use as a fuel.

evaporator: A closed vessel heated by steam and placed under a vacuum. The basic principle is that syrup enters the evaporator at a temperature higher than its boiling point under the reduced pressure, or is heated to that temperature. The result is flash evaporation of a portion of the liquid.

excise tax exemption (gasoline): P.O. 95-618 exempts gasoline used for blending with alcohol from 4 cents Federal excise tax. Many states have similar exemptions.

experimental permit: ATF temporary permit which allows experimentation or development of materials for the production of distilled spirits, processes for the production or distillation of distilled spirits or industrial use of distilled spirits. Ethanol produced cannot be sold or given away.

feedstock preparation: The process by which the raw material is converted to a saccharified mash which can be fermented. The process varies according to the feedstock used.

feed wort: A mixture of cane and beet molasses that is diluted with water, clarified, sterilized, and pH adjusted, and used to provide carbon, sugar, and other nutrients necessary for yeast growth.

fermentation: The production of ethanol and carbon dioxide from fermentable carbohydrates by the action of yeast.

fermentation ethanol: Ethanol obtained by the fermentation of renewable biomass feedstocks.

FGD: Flue Gas Desulfurization.

filter: A device or structure from removing solid or colloidal matter from a liquid. The filtering medium consists of a granular material, finely woven cloth, unglazed porcelain, or specially prepared paper.

filter press: In the past the most common type of filter used to separate solids from sludge. It consists of a simple and efficient plate and frame filter.

fixed beds: A filter or adsorption bed where the entire media is exhausted before any of the media is cleaned.

flocculant: A substance that induces or promotes fine particles in a colloidal suspension to aggregate into small lumps, which are more easily removed.

flotation: The raising of suspended matter to the surface of the liquid in a tank as scum - by aeration, the evolution of gas, chemicals, electrolysis, heat, or bacterial decomposition - and the subsequent removal of the scum by skimming.

fusel oil: An inclusive term for heavier, pungent-tasting alcohols, principally anyl and butyl alcohols, removed through rectification.

Gasohol: A registered trademark held by the State of Nebraska for a fuel mixture of 10 percent anhydrous ethanol and 90 percent unleaded gasoline; it is often used to mean any mixture of alcohol and gasoline to be used for motor fuel.

germicidal treatment: Any treatment involving killing of micro-organisms through the use of disinfecting chemicals.

GPD: Gallons per day.

GPM: Gallons per minute.

granular media filtration: A filtration process which consists of passing wastewater through a packed bed of granular material with the solids in the wastewater depositing onto the granular media.

heads: A distillate containing a high percentage of low-boiling components such as aldehydes.

hydrolysis: The chemical splitting of a bond which results in a new compound and water.

hygroscopic: Tending to absorb moisture from the atmosphere.

impoundment: A pond, lake, tank, basin, or other space which is used for storage of wastewater.

industrial wastes: The liquid wastes from industrial processes, as distinguished from sanitary wastes.

industrial wastewater: Wastewater in which industrial wastes predominate.

ion exchange: A chemical process in which ions from different molecules are exchanged.

ion exchange resins: Resins consisting of three-dimensional hydrocarbon networks to which are attached ionizable groups.

ketone (Webster): An organic compound with a carbonyl group attached to two carbon atoms.

Kraus Process: A modification of the activated sludge process in which aerobically conditioned supernatant liquor from anaerobic digesters is added to activated sludge aeration tanks to improve the settling characteristics of the sludge and to add an oxygen resource in the form of nitrates.

lagoon: A pond containing raw or partially treated wastewater in which aerobic and anaerobic stabilization occurs.

lean fuel mixture: An excess of air in the air/fuel ratio. Gasohol has a leaning effect over gasoline because the ethanol adds oxygen to the system.

mash: Grain which has been steeped in hot water. During the mashing process, the starch in grain is converted to fermentable sugars.

mashing: The process involving cooking, gelatinization of starch, and conversion, changing starch into grain sugar.

membrane technology: Works by a process of osmosis. In a highly simplified explanation, the membranes act as a screen or filter, only allowing certain substances to pass through. A membrane would allow ethanol to pass through while stopping stillage, sugars, and water. The final result of membrane technology is two hundred proof ethanol which is less expensive to produce.

metabolism: The sum of the processes concerned in the building up of protoplasm and its destruction incidental to life; the chemical changes in living cells by which energy is provided for the vital processes and activities and new material is assimilated to repair the waste.

methanol (methyl alcohol): An alcohol which can be produced by destructive distillation of wood or urban wastes and used as a gasoline extender; most of the methanol used today is produced from natural gas; coal may also be converted into methanol; also known as wood alcohol or methyl alcohol; methanol when mixed with gasoline, tends to separate from the gasoline under certain conditions; methanol will also enhance gasoline octane.

ug/l: Micrograms per liter (equals parts per billion (ppb) when the specific gravity is unity).

MGD: Million gallons per day.

mg/l: Milligrams per liter (equals parts per million (ppm) when the specific gravity is unity).

mixed liquor: A mixture of activated sludge and organic matter undergoing activated sludge treatment in the aeration tank.

mixed media filtration: A combination of different materials through which a wastewater or other liquid is passed for the purpose of purification treatment, or conditioning.

moisture: Loss in weight due to drying under specified conditions, expressed as percentage of total weight.

moisture content: The quantity of water present in a sludge expressed in percentage of net weight.

molasses: A dark-colored syrup containing sugar produced as a by-product in cane, citrus, and beet sugar processing and in the production of citrus concentrates.

mostos: The stillage produced by cane and citrus molasses distillers which has less nutritional value than grain stillage.

multiple effect evaporation: The operation of evaporators in a series.

municipal sewage: The spent water of a community. See wastewater.

MSW (Municipal Solid Waste): In regard to this document the term refers to waste with potential for conversion to methanol.

net BOD: The amount of BOD added by a process; the difference between the BOD load of a plant's discharge and its intake.

neutralization: The process of pH adjustment which results in a final solution pH of 7. Depending on the influent solution's pH, either acid or base is added to achieve a neutral solution.

noncontact wastewaters: Those wastewaters such as spent cooling water which are independent of the manufacturing process and contain no pollutants attributable to the process.

NO_x: Nitrogen Oxides.

NPDES: National Pollutant Discharge Elimination System.

NSPS: New Source Performance Standards.

nutrients: The nutrients in contaminated water are routinely analyzed to characterize the food available for microorganisms to promote organic decomposition. They are:

Ammonia Nitrogen (NH_3), mg/l as N Kjeldahl Nitrogen (ON), mg/l as N Nitrate Nitrogen (NO_3), mg/l as N;

Total Phosphate (TP), mg/l as P Ortho Phosphate (OP), mg/l as P

O&G (Oil and grease): Wastewater parameter measuring nonsoluble organic fraction.

Operating Permit for Distilled Spirits Plant: ATF permit required if the distilled spirits plant will produce ethanol only for nonbeverage industrial use (e.g., a Gasohol plant).

osmotic pressure: The pressure associated with the diffusion of substances through a semi-permeable membrane, such as a cell membrane. The osmotic pressure is related to the molar concentration of the medium and the absolute temperature.

OSW: Office of Solid Waste (EPA).

ozonation: The saturation of a solution with ozone, resulting in disinfection of the solution.

PCTM: Pollution Control Technical Manual.

pH: pH is a measure of the negative log of hydrogen ion concentration.

pitching: Adding yeast to a solution to cause fermentation.

PNA: Polynuclear Aromatics.

polluted wastewaters: Those wastewaters containing measurable quantities of substances that are judged to be detrimental to receiving waters and that are attributable to the process.

polyelectrolytes: Usage of this term in a document refers to a coagulant aid consisting of long chained organic molecules.

POTW: Publically Owned Treatment Works.

ppb: parts per billion. See micrograms/liter.

ppm: parts per million. See milligrams/liter.

precoat filter: A type of filter in which the media is applied to an existing surface prior to filtration.

preliminary filter: A filter used in a water treatment plant for the partial removal of turbidity before final filtration.

preliminary treatment: Those processes used to protect or optimize the performance of downstream units at a wastewater treatment facility. Preliminary treatment provides no pollutant removal; it is a control system to ensure effective operation. The processes used are bar screening, equalization, and neutralization.

primary treatment: The removal of suspended solids by physical means. The processes used are coarse screening and sedimentation, which remove approximately 10 percent of the influent suspended solids.

proof: Alcoholic content of a liquid at 16°C (60°F), stated as twice the percentage of ethanol by volume (United States definition).

proof gallon: A standard U.S. gallon containing 50 percent ethanol by volume.

raw wastewater: Wastewater prior to treatment.

reboiler: A kettle used to heat the bottoms of a column which will be recycled to the column inlet.

rectification: Usually referring to the redistillation of certain goods for the purpose of increasing purity, concentration, or quality.

returned sludge: Settled activated sludge returned to mix with incoming wastewater.

rich fuel mixture: An excess of fuel in the air/fuel ratio.

ridge and furrow irrigation: A method of irrigation by which water is allowed to flow along the surface of fields.

rotary vacuum filter: A rotating drum filter which utilizes suction to separate solids from the sludge produced by clarification.

rotating biological contactor (RBC): A set of molded disks that have a thin biological film growing on the surface. These disks are partially submerged in a cylindrical tank and are rotated. RBC's are used for secondary treatment.

roughing filter: (1) A wastewater filter of relatively coarse material operated at a high rate to afford preliminary treatment, (2) For water treatment, see preliminary filter.

sanitary sewage, sanitary wastewater: Liquid wastes from residences or commercial establishments, as distinguished from industrial wastes.

secondary wastewater treatment: The treatment of sanitary sewage by biological methods after primary treatment by sedimentation, usually considered to remove 90 percent or more of the influent BOD.

settleable solids: See solids.

settlings: The material which collects in the bottom portion of a clarifier.

settling pond: See clarifier.

sewerage: System of piping, with appurtenances, for collecting and conveying wastewater from source to discharge.

skimming: The process of removing floating grease or scum from the surface of wastewater.

sludge: The accumulated solids separated from wastewater during treatment.

sludge cake: Sludge that has been dewatered to a moisture content of 60 to 85 percent.

sludge dewatering: The process of removing the moisture content of a sludge to such an extent that the sludge is spadable.

sludge digestion: The process by which organic or volatile matter in sludge is gasified, liquefied, mineralized, or converted to a more stable organic matter through the activities of either anerobic or aerobic organisms.

sludge drying: The process of removing a large percentage of moisture from sludge by drainage or evaporation.

sludge thickening: The process of increasing the solids concentration of a sludge, but not to such an extent that the sludge is spadable.

sludge handling: The transport, storage, treatment, and disposal of sludge.

slurry: A watery mixture or suspension of insoluble matter.

solids: Various types of solids are commonly determined on water samples. These types of solids are:

Total Solids (TS): The material left after evaporation and drying of a sample at 100° to 105°C.

Dissolved Solids (TDS): The difference between suspended solids and total solids.

Volatile Suspended Solids (VSS): Organic matter which is lost when the sample is heated to 550°C.

Settleable Solids (SS): The materials which settle in an Imhoff cone in one hour.

Total Suspended Solids (TSS): The material removed from a sample filtered through a standard glass fiber filter and dried at 103° to 105°C.

solvent extraction: The stripping of a component of a solution by use of a solvent.

SO_x: Sulfur Oxides.

spadable sludge: Sludge that can be readily forked or shoveled, ordinarily under 75 percent moisture.

spent beer: Residual nutrients separated from harvested yeast by centrifugal separation.

spent grains: Residual grains following their utilization in the processing of ethanol. These by-products are usually marketed as animal feeds.

spent sulfite liquor (SSL): The lignins/sugar solution separated from the fibrous cellulosic material in wood preparation.

spray evaporation: A method of wastewater disposal in which water is sprayed into the air to expedite evaporation.

spray irrigation: A method of irrigation by which water is sprayed.

stillage (or still slops): The waste dealcoholized liquid from the beer stills.

synthetic ethanol: Ethanol produced from ethylene as opposed to fermentation ethanol, which is obtained from the fermentaation of renewable biomass sources.

tax-free alcohol: Pure ethyl alcohol withdrawn free of tax for government, for science or for humanitarian reasons. It cannot be used in foods or beverages. All purchases outside of the government must obtain permits, post bonds, and exert controls upon storage and use of tax-free alcohol.

tax-paid alcohol: Pure ethyl alcohol which has been released from Federal bond by payment of the Federal tax of $21.00 per gallon at 200 proof or $19.95 per gallon at 190 proof.

tertiary treatment: The processes which follow secondary treatment in a wastewater treatment facility. These processes provide further removal of pollutants and are granular media filtration, land application, and air flotation.

TOC: Total Organic Carbon.

TSP: Total Suspended Particulates.

TSS: Total Suspended Solids.

VOC: Volatile Organic Carbon.

volumetric fuel economy: Miles per gallon.

whey: The water part of milk separated from the curd in the process of making cheese; it is a by-product produced commercially in large quantities and can be used as a fertilizer, animal feed or in the production of ethanol.

yeast: Microscopic unicellular organism responsible for alcoholic fermentation.

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